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Volume 2 NOVEMBER, 1921 Number 11

Sunshine Efficiency of Hog Houses*

By Frank C. Harris

Mem. A.S.A.E. Director of Agricultural and Industrial Engineering, The Louden Machinery Company

SUNLIGHT in the hog house promotes sanitation, warmth, and dryness—three of the prime requisites for the healthful housing of swine. It seems to have an additional vitalizing influence on animals, particularly young pigs, which is not a direct result of the disinfection, warmth, and dryness. It seems to promote the proper functioning of their bodily organs.

Sunlight is the great natural disinfectant. Bacterial life is found almost everywhere but exists in the more dangerous forms in damp, dark, warm places. A very favorable condition for the development of germ life would be found in the dark, close hog house in which the beds were used continously for a few weeks, and no argument is necessary to show that this is an unfavorable condition for young pigs to live in. Many forms of bacterial life cannot stand strong sunlight and dryness is unfavorable to their propagation. Sunlight is the great natural agent which keeps bacterial life under reasonable control. When admitted to the hog-house the sun's rays not only disinfect to a considerable extent the nests, floors, and pens where the hogs are kept, but they also dry up the offal, promote ventilation, and disperse foul odors which swine because of their low stature would otherwise be compelled to breathe.

These considerations are too well understood to justify more than a brief mention here. It is the main purpose of this discussion to consider and investigate the methods of and types best adapted to obtaining sunshine in the hog house at the proper place rather than the benefit derived from it.

As to warmth, experiments conducted in Massachusetts by Mr. Cabot and others with rooms and boxes thoroughly insulated on all sides except one, which was covered with glass, show that more heat may be collected in this way than is ordinarily thought possible. They were able to obtain summer temperatures inside of these boxes during the day in winter weather. This emphasizes the fact that hog houses should be insulated thoroughly against heat loss, and may be constructed to constitute, in effect, sun boxes which will trap a large amount of the sun's warmth. These experiments also

*A paper to be presented at the fifteenth annual meeting of the American Society of Agricultural Engineers to be held in Chicago, December 27, 28 and 29.

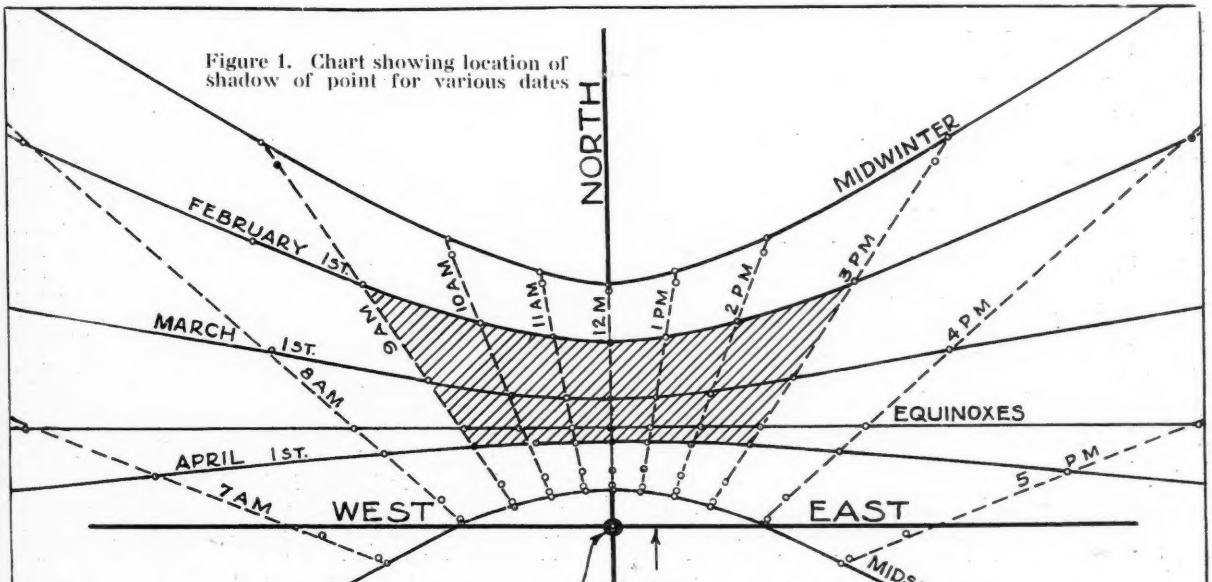
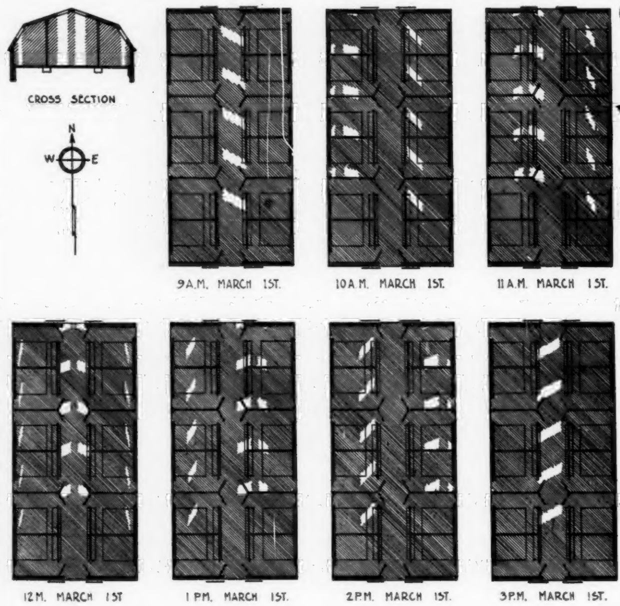


Figure 1. Chart showing location of shadow of point for various dates



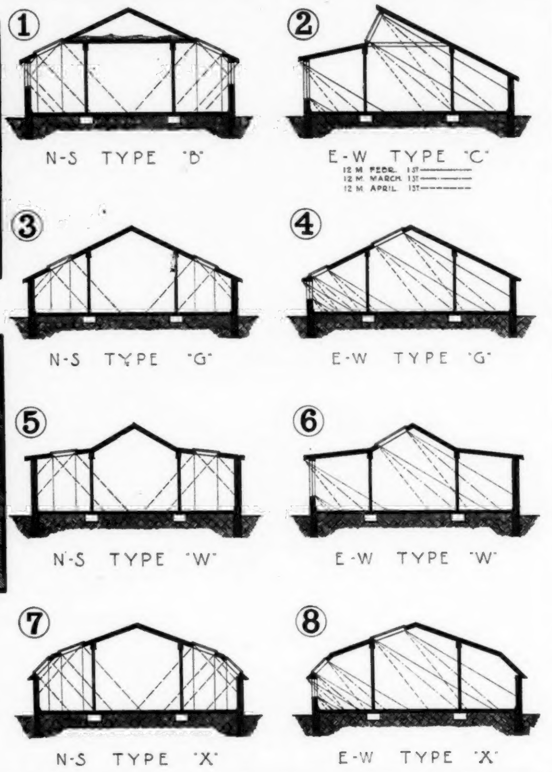


Figure 2. (Right) Chart showing sun patterns for a common type of hog house

Figure 3. (Above) Chart of selected cross sections

suggest that the windows in the hog house should face the sun's rays as nearly perpendicularly as possible throughout the day. The sun's rays are as warm in winter as they are in summer but because of the shortness of the day, their slant, and the condition of the earth are reflected away from the earth's surface and much of their warmth is not retained.

Much has been written regarding sunlight in hog houses; tables have been prepared giving the height of a window set at a certain distance from the bed in order to get the sunshine at the proper place on a given date; buildings have been designed to obtain as much benefit as possible from the sunlight. This has all contributed greatly to the development of the best types of hog houses, but there is still a vagueness as to the actual amount and location of the sun spots thrown into the pens by the windows of these types of buildings. This is easy to understand when we remember that the slant of the sun's rays varies with each hour of the day and each day of the year, and there is at the same time a daily and hourly change in angle between the meridian and the position of the sun.

The difference in angle which the sun's rays make with the ground at noon between midwinter and midsummer is approximately 47 degrees. During the farrowing period from February 1 to April 15 the variation in angle with the ground at noon is 27½ degrees. From midwinter, December 21, to February 1, the change in angle is 6 degrees; from February 1 to March 1 the change is 10 degrees; from March 1 to April 1, which covers the equinoctial period and therefore the greatest rate of change in angle, the change is 12 degrees. The change in direction of sun's rays with reference to the meridian is not so important but has some influence. The sun rises on February 1 at a point about 67 degrees east of south at a few minutes after seven o'clock in the morning, while on April 15 it rises 77 degrees east of north at about five-thirty in the morning. The difference in the direction of the sun's rays at sunrise over this period is 36 degrees, and the variation in the time is more than one and one-half hours.

The accompanying drawing (Fig. 1) shows the various points at which the shadow of a point, located as shown by the heavy black circle, would be thrown on the given dates and at different hours of the day, and illustrates the change in the position of the shadow due to the seasonal change in the slant and direction of the sun's rays. The black curves show the path which the shadow of the point would take on various dates and seasons. Heavy lines or curves are shown for midwinter, the equinoxes and midsummer, and for the first days of February, March, and April. The dotted lines are the hour lines upon which the shadow will fall on the hours given. The intersection of the dotted hour lines with the heavy date lines give the position of the shadow on any given date and hour. During each half year the shadow of the point will fall anywhere in the area between the two outer curves which are those for midwinter and midsummer. The shaded area in the chart covers the various positions of the shadow for the principal part of the farrowing season, which the investigations outlined in subsequent paragraphs were made to cover. The different positions of the shadow of the point shown in the drawing correspond exactly to the sun spot or pattern which rays of light would make by passing through the roof window of a hog house.

The need for exact information is apparent if reliable results are to be obtained. For this reason the drawings which follow were based on astronomical data contained in "The American Ephemeris and Nautical Almanac for 1920" published by the U. S. Naval Observatory. Charts giving the slant, direction, and projections of the sun's rays for each hour and date under consideration were made from this data. The time referred to in each case is sun time which varies slightly from the prevailing standard time in some localities, but is much better for this purpose and is correct for all places.

The investigations were limited to the hours of nine, ten, eleven, twelve, one, two, and three o'clock sun time for the following reasons:

1. The intensity of the sunshine during the middle of the day is much greater than at early morning and late evening.

2. Due to the angle at which the early and late sun's rays strike most of the windows the reflection is great and the effectiveness of the sunshine is reduced until it is of comparatively little value.

3. The oblique rays of the sun passing through the window during the early morning and late evening produce sunlight patterns of large area but of very little value and thus their influence on results would be somewhat misleading.

4. The thickness of the walls and roof in which the windows are placed has a tendency to reduce the size of the morning and evening pattern to a degree which is problematical.

The investigations and sunshine charts were made for 42 degrees and north latitude. The forty-second parallel strikes slightly to the north of the middle of the corn and hog belt and is about the center of the hog-raising territory having a sufficiently severe climate to demand tightly built winter quarters for swine. The observations made will not be greatly amiss for other latitudes when taking into consideration the fact that the comparatively low range of latitude for the United States which requires careful consideration is about 12 degrees. The difference in angle of the sun's rays with the ground on any date is equal to the difference in latitude between any two points under consideration, therefore, the maximum variation in the angle of the rays on the forty-second parallel and at other points in the belt under consideration will be 6 degrees, or one half of the total range.

Six degrees change in angle of the sun's rays, or in latitude, would make a difference in the height of the window at the ridge of a hog house of about one foot when sun patterns were thrown in the same relative position in the building. It should not be forgotten that the severity of the cold in the north makes farrowing in general slightly later in the year, so that the change in season and corresponding change in the angle of the sun's rays during this period will partly offset each other. The change in angle of the sun's rays with the ground at noon is about one-third degree per day. This being true the only difference in window location from that shown in the cross sections accompanying this discussion will be to shift the upper roof windows up to the ridge in the construction of buildings for points five degrees or more to the south of the forty-second parallel, or to move the window down the roof eight or ten inches for locations five degrees or more to the north of this parallel.

Fig. 2 shows a drawing of the sunlight or sun patterns made for a hog house in common use. The building runs north and south. It is a gambrel roofed building of the better types in use at the present time and will illustrate that further inprovement may be made by changing the roof lines and relocating the windows. There are two 2′ 0″ by 2′ 3″ window openings to each pen having only nine square feet of glass per pen, and this is more than many hog houses contain. These sun patterns were obtained by the use of the charts already mentioned. Each window opening was projected obliquely down upon the floor. The projection was made in the direction and slant of the sun's rays upon the hour and date indicated, producing the sun patterns as shown. This example illustrated the general method followed in making the entire investigation. The patterns were carefully drawn and their areas measured by scaling where they were regular in form. A polar planimeter was used where the patterns were irregular or difficult to scale.

A pen section of the building was taken as the unit and basis of investigation. A pen section consists of a section of the hog house as long as the one pen is wide, namely, eight feet. It contains two eight-foot pens, one on each side of central alley, and a typical set of windows, beds, troughs, and floor areas. The sun patterns for one pen section only are shown in the following drawings, but a large floor area must be used since the windows in one pen section generally throw their patterns into another pen section, and in turn receive patterns from the pen section on the other side.

The efficiencies of the various types with regard to admitting sunlight to the proper places in the buildings were calculated by the following method. Sun patterns for all the windows in the pen section were made for nine, ten, eleven, twelve, one, two, and three o'clock on the date under consider-

TABLE II

COMPARATIVE EFFICIENCIES, E-W BUILDINGS

E.W. TYPE	UPPER ROOF WINDOW			LOWER ROOF WINDOW			WALL WINDOW			TOTALS			EFFICIENCY ALL WINDOWS	
	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	TOTAL GLASS	AVERAGE SQ. FT. SUN ON FLOOR	AVERAGE SQ. FT. SUN ON BED	FLOOR	BED
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C	30	1.02	.39				8½	1.15	.57	38½	40.1	16.6	1.04	.43
G	15	1.04	.42	8	1.38	.38	8	1.07	.66	31	35.2	14.7	1.14	.47
W	15	1.04	.43				8½	1.15	.57	23½	25.4	11.3	1.08	.48
X	15	1.04	.35	8⅓	1.49	.41	8	1.07	.66	31⅓	37.4	14.1	1.19	.45
AVERAGE													1.08	.45

TABLE III

COMPARATIVE EFFICIENCIES, N-S BUILDINGS

N-S TYPE	WINDOW ARRANGEMENT	EAST ROOF WINDOW			EAST WALL WINDOW			WEST ROOF WINDOW			WEST WALL WINDOW			TOTALS			EFFICIENCY ALL WINDOWS	
		SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	TOTAL GLASS	AVERAGE SQ. FT. SUN ON FLOOR	AVERAGE SQ. FT. SUN ON BED	FLOOR	BED
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
G	INDIV	11	.82	.25				11	.82	.25				22	18.1	5.5	.82	.25
W	"	11	.77	.21				11	.77	.21				22	15.7	4.6	.71	.21
X	"	11	.77	.20	9	*.68	*.23	11	.77	.20	9	*.68	*.23	40	29.3	8.6	.73	.21
B	REG	20	.66	.21	12	.46	.15	20	.66	.21	12	.46	.15	64	37.5	11.9	.59	.18
G	CONT	22	.82	.15				22	.82	.15				44	36.1	6.9	.82	.15
W	"	22	.77	.25				22	.77	.25				44	31.5	10.6	.71	.24
X	"	27	.75	.21				22	.75	.21				44	33.	9.5	.75	.21
AVERAGE ALL																	.73	.21
"	INDIV																.75	.22
"	CONT																.76	.20

* LOWER SLOPE OF ROOF IN N-S TYPE "X"

TABLE IV

EFFICIENCY OF BUILDING SET DIAGONALLY

DIAGONAL OR NE-SW TYPE	WINDOW ARRANGEMENT	LOCATION OF BED	UPPER ROOF WINDOW			LOWER ROOF WINDOW			WALL WINDOW			TOTALS			EFFICIENCY ALL WINDOWS	
			SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	SQ. FT. GLASS	EFFICIENCY FLOOR	EFFICIENCY BED	TOTAL GLASS	AVERAGE SQ. FT. SUN ON FLOOR	AVERAGE SQ. FT. SUN ON BED	FLOOR	BED
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
G	REG. E-W	S-W	15	.88	.23	8	1.23	.38	8	.91	.41	31	30.4	9.8	.98	.32
"	" "	N-E	15	.88	.22	8	1.23	.36	8	.91	.52	31	30.4	10.3	.98	.33
			SOUTH EAST ROOF			NORTH WEST ROOF										
"	IND. N-S	S-W	11	1.28	.32	11	.30	.17				22	17.3	5.3	.79	.24
"	" "	N-E	11	1.28	.29	11	.30	.17				22	17.3	5.	.79	.23
AVERAGE															.885	.28

TABLE V

COMPARATIVE DATA

BASED UPON ONE 8 FT. PEN SECTION

TYPE	DIRECTION	WINDOW ARRANGEMENT	SQ. FT. CROSS SECTION	CU. FT. AIR	EXPOSURE				AVERAGE SQ. FT. SUN		SUNSHINE EFFICIENCY	
					TWO ENDS	SIDE WALLS	ROOF	GLASS	FLOOR	BED	FLOOR	BED
1	2	3	4	5	6	7	8	9	10	11	12	13
B	N-S	REG.	173	1384	346	100	129*	64.	37.5	11.9	.59	.18
C	E-W	REG.	173	1384	346	82	216	38.5	40.1	16.6	1.04	.43
G	E-W	REG.	153	1224	306	64	200	31.	35.2	14.7	1.14	.47
G	N-S	IND.	153	1224	306	64	200	22.	18.1	5.5	.82	.25
G	N-S	CONT.	153	1224	306	64	200	44.	36.1	6.9	.82	.15
G†	NE-SW	E-W	153	1224	306	64	200	31.	30.4	10.3	.98	.33
G†	NE-SW	N-S	153	1224	306	64	200	22.	17.3	5.0	.79	.23
W	E-W	REG.	162	1296	324	98	192	23.5	25.4	11.3	1.08	.48
W	N-S	IND.	162	1296	324	98	192	22.	15.7	4.6	.71	.21
W	N-S	CONT.	162	1296	324	98	192	44.	31.5	10.6	.71	.24
X	E-W	REG.	164	1312	328	64	208	31.3	37.4	14.1	1.19	.45
X	N-S	IND.	164	1312	328	64	208	40.	29.3	8.6	.73	.21
X	N-S	CONT.	164	1312	328	64	208	44.	33.	9.5	.75	.21
AVERAGES			165	1320	330	81	189	35.6	29.8	10.0	.87	.30

*STRAW COVERED CEILING, HALF EXPOSURE COUNTED † NOT COUNTED IN AVERAGES

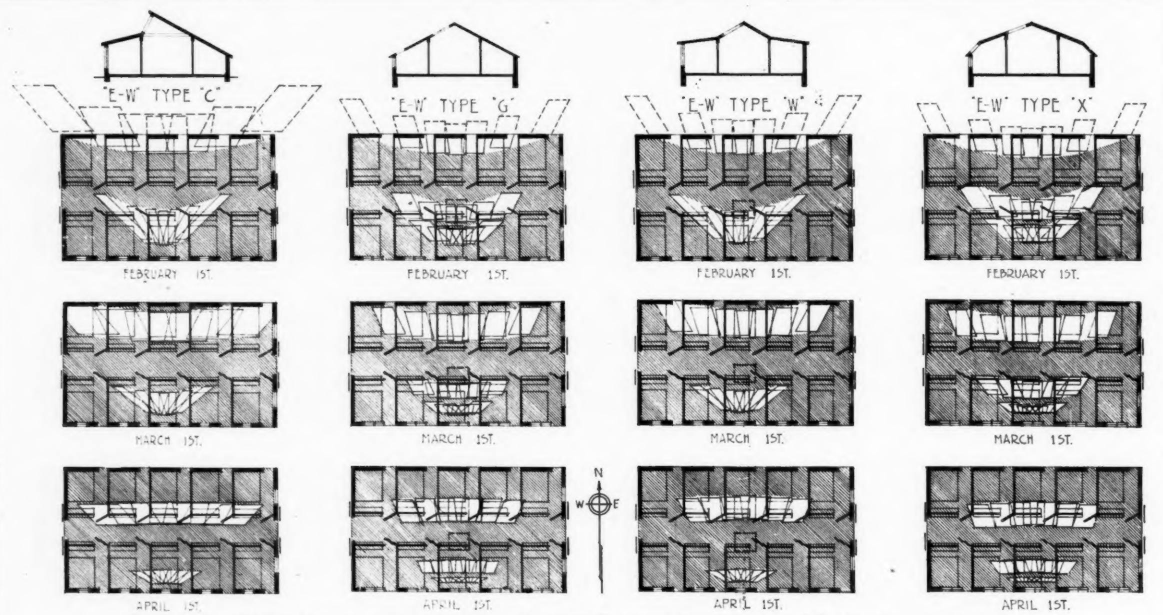


Figure 4. Chart showing sun patterns of all E-W types for Feb. 1st, March 1st, and April 1st

ation. All these patterns were measured and the total sunshine area divided by number of hours to obtain the average sunshine area for the day. This result was divided by the total glass area in the pen section, the result being the efficiency of the type on that day.

The pattern for each hour is taken as the average for the hour beginning one-half hour before and ending one-half hour after the hour indicated. That is, the pattern for nine o'clock represents the hour from eight-thirty to nine-thirty.

Thus, the efficiency basis on which the results are calculated is the average area of sunshine, expressed in square feet, which one average square foot of glass will admit to the floor or bed continuously from 8:30 A. M. until 3:30 P. M.

The figures given in Table 1 accompanying the sun pattern drawings of the different types show two sets of readings. The first readings were taken on the entire floor of the hog house and were used to calculate the efficiencies with respect to the floor. The second measurements include only the sun patterns or portions of patterns falling on the bed, and give the figures with respect to the beds alone. The results in Tables II, III, and IV, which are based on the data given in Table I, give in the last two columns the efficiencies of the different types for the entire spring farrowing period for floor and bed, respectively. They were obtained by drawing and measuring patterns for February 1, March 1, and April 1, and figuring the average sunshine area obtained for the three dates using the method described above.

The beds are assumed to be five by six feet, which is small enough to avoid results which would be misleading. In general they are placed on the north side of the pens in north-south buildings and to the west side of pens in east-west buildings. Pens are assumed to be eight feet wide. If six-foot pens are used, however, the results would be comparable. No interference to the sun's rays by paneling is assumed.

Fig. 3 shows the cross sections of a number of buildings designed for special investigation after a careful preliminary study of existing types in common use. North-south types, B, G, W, and X, shown on the left side of the drawing, have their windows arranged for buildings designed to run north and south, while east-west types, C, G, W, and X shown on the right-hand side of the plate have windows arranged for buildings designed to run east and west. B is a north-south type only, while C is an east-west type only. G, W, and X may be used as either type by making proper changes in the window arrangement. These designs embody the best features of the designs studied in the preliminary investigation and a comparison of the sun patterns in Fig. 2 with the sun patterns of these types will show the improvement.

There is a considerable amount of repetition of similar patterns in Fig. 2. For this reason in Fig. 4 only the windows for one pen section were used. Instead of showing the patterns for each hour on the given date on separate floor plans, the patterns for one pen section for all seven hours are shown on a single plan. The patterns produced each hour are outlined with a light line. This method of showing the patterns, while it does not show the sunshine distribution so clearly, requires only one plan for each day instead of one for each hour. A set of sun patterns which will be typical of the entire building, regardless of type or length, will be secured by this method. The results obtained by studying one pen section from each type can then be compared.

The length of the building is assumed to be indefinite. One pen section at each end of a hog house would have less sunshine than the central areas and, therefore, the efficiencies for shorter buildings would be less, but the same thing is true for all types so that comparisons will not be affected.

Fig. 4 gives the sun patterns for all of the east-west types shown in Fig. 3 for February 1, March 1, and April 1. The floor plans used have five pen sections, or ten pens, but the sun patterns on these plans were made by the windows in the central pen section only. The sun patterns for February 1 are outlined in dotted lines as they would extend outside of the building if the north wall were removed. The patterns actually strike the north wall and would furnish a considerable amount of indirect or reflected light. A sow lying down along the north wall of a pen, since her body would extend several inches above the pen floor, would catch a larger amount of the slanting rays of sunshine than the pattern indicates.

By March 1 practically all of the sun patterns in these

Table I—Measurements of All Sun Patterns

Section	Type	Date	Position of Window	Area of Glass	Area per Pen Sect.	Area of Sunshine Patterns in Sq. Ft. on Floor and Beds: 9 A.M. FL.	9 A.M. BED	10 A.M. FL.	10 A.M. BED	11 A.M. FL.	11 A.M. BED	12 M FL.	12 M BED	1 P.M. FL.	1 P.M. BED	2 P.M. FL.	2 P.M. BED	3 P.M. FL.	3 P.M. BED	Total Area on Floor	Total Area on Bed	Av. Area on Floor	Av. Area on Bed	Window Efficiency for Floor	Window Efficiency for Bed	Eff. for Fl. All W'dows. for Month	Eff. for Bed All W'dows for Month
E-W	C	FEB. 1	ROOF	30.00		0.0	0.0	13.0	8.0	21.0	10.5	24.0	15.0	21.0	10.5	13.0	9.5	0.0	0.0	92.0	53.5	13.2	7.7	0.44	0.26		
E-W	C	FEB. 1	WALL	8.50	38.50	17.5	1.3	14.0	4.0	13.5	8.0	13.0	8.0	13.5	7.5	14.0	3.0	17.5	2.8	103.0	34.5	14.7	4.9	1.73	0.57	0.72	0.33
E-W	C	MAR. 1	ROOF	30.00		41.2	26.5	46.0	30.0	46.0	26.0	46.0	25.0	46.0	27.5	46.0	30.0	43.0	27.0	314.0	192.0	44.9	27.4	1.50	0.91		
E-W	C	MAR. 1	WALL	8.50	38.50	10.0	2.5	9.0	5.0	9.0	9.0	8.5	8.5	9.0	8.0	9.0	4.0	10.0	5.0	64.5	42.0	9.2	6.0	1.07	0.70	1.40	0.87
E-W	C	APR. 1	ROOF	30.00		32.0	0.0	33.0	0.0	34.0	0.0	34.0	0.0	34.0	0.0	33.0	0.0	32.0	0.0	232.0	0.0	33.2	0.0	1.11	0.00		
E-W	C	APR. 1	WALL	8.50	38.50	5.0	1.5	5.3	4.0	5.5	5.5	5.8	5.8	5.5	5.5	5.3	3.3	5.0	1.5	37.3	27.0	5.3	3.9	0.66	0.45	1.00	0.10
E-W	G	FEB. 1	UPPER RF.	15.00		0.0	0.0	7.8	7.0	12.0	8.3	13.3	10.5	12.0	4.5	7.8	4.8	0.0	0.0	53.0	35.0	7.6	5.0	0.51	0.33		
E-W	G	FEB. 1	LOWER RF.	8.00		15.8	0.0	13.3	0.0	12.8	0.0	12.0	0.0	12.8	0.0	13.3	0.0	15.8	0.0	95.8	0.0	13.7	0.0	1.71	0.00		
E-W	G	FEB. 1	WALL	8.00	31.00	16.0	4.5	13.0	10.8	12.8	12.8	12.0	9.6	12.8	6.8	13.0	4.5	16.0	8.5	95.5	57.5	13.7	8.2	1.71	1.03	1.13	0.43
E-W	G	MAR. 1	UPPER RF.	15.00		22.0	8.3	21.8	10.6	21.0	13.0	20.5	13.8	21.0	5.5	21.8	19.0	22.0	17.2	150.0	87.3	21.4	12.5	1.43	0.83		
E-W	G	MAR. 1	LOWER RF.	8.00		1.5	1.0	11.0	2.3	11.0	5.5	11.0	4.5	11.0	2.0	11.0	2.0	11.5	2.0	68.0	19.3	9.7	2.8	1.21	0.35		
E-W	G	MAR. 1	WALL	8.00	31.00	9.0	4.3	8.0	7.5	7.0	7.0	7.0	5.7	7.0	2.0	8.0	4.0	9.0	4.0	55.0	34.5	7.9	4.9	1.01	0.61	1.26	0.65
E-W	G	APR. 1	UPPER RF.	15.00		17.5	1.6	17.8	0.8	18.0	2.0	18.5	2.5	18.0	11.0	17.8	2.0	17.5	1.0	125.0	11.0	17.9	1.6	1.19	0.11		
E-W	G	APR. 1	LOWER RF.	8.00		9.5	3.0	9.5	6.8	10.0	10.0	10.0	8.0	10.0	4.5	9.5	3.5	9.5	7.5	68.0	43.5	9.7	6.2	1.21	0.78		
E-W	G	APR. 1	WALL	8.00	31.00	4.0	3.5	4.0	4.0	4.0	3.9	4.0	3.3	4.0	2.5	4.0	1.5	4.0	1.0	28.0	19.8	4.0	2.8	0.50	0.35	1.02	0.34
E-W	W	FEB. 1	ROOF	15.00		0.0	0.0	7.8	7.0	12.0	8.3	13.3	10.5	12.0	4.5	7.8	4.8	0.0	0.0	53.0	35.0	7.6	5.0	0.51	0.33		
E-W	W	FEB. 1	WALL	8.50	23.50	17.5	1.3	14.0	4.0	13.5	8.0	13.0	8.0	13.5	7.5	14.0	3.0	17.5	2.8	103.0	34.5	14.7	4.9	1.73	0.57	0.95	0.42
E-W	W	MAR. 1	ROOF	15.00		22.0	8.3	21.8	10.6	21.0	13.0	20.5	13.8	21.0	5.5	21.8	19.0	22.0	17.2	150.0	87.3	21.4	12.5	1.43	0.83		
E-W	W	MAR. 1	WALL	8.50	23.50	10.0	2.5	9.0	5.0	9.0	9.0	8.5	8.5	9.0	8.0	9.0	4.0	10.0	5.0	64.5	42.0	9.2	6.0	1.07	0.70	1.30	0.79
E-W	W	APR. 1	ROOF	15.00		17.5	1.6	17.8	0.8	18.0	2.0	18.5	2.5	18.0	1.0	17.8	2.0	17.5	1.0	125.0	11.0	17.9	1.6	1.19	0.11		
E-W	W	APR. 1	WALL	8.50	23.50	5.0	1.5	5.3	4.0	5.5	5.5	5.8	5.8	5.5	5.5	5.3	3.3	5.0	1.5	37.3	27.0	5.3	3.9	0.66	0.45	0.99	0.23
E-W	X	FEB. 1	UPPER RF.	15.00		0.0	0.0	11.0	11.0	13.5	7.6	16.0	11.2	13.5	9.6	11.0	6.0	0.0	0.0	65.0	45.4	9.3	6.5	0.62	0.43		
E-W	X	FEB. 1	LOWER RF.	8.33		17.0	0.0	16.0	0.0	15.0	0.0	14.0	0.0	15.0	0.0	16.0	0.0	17.0	0.0	110.0	0.0	15.7	0.0	1.88	0.00		
E-W	X	FEB. 1	WALL	8.00	31.33	16.0	4.5	13.0	10.8	12.8	12.8	12.0	9.6	12.8	6.8	13.0	4.5	16.0	18.5	95.5	57.5	13.7	8.2	1.71	1.03	1.23	0.47
E-W	X	MAR. 1	UPPER RF.	15.00		20.0	6.4	19.2	8.8	19.2	8.8	19.0	10.8	19.2	4.8	19.2	12.2	20.0	14.4	135.8	66.2	19.3	9.5	1.29	0.63		
E-W	X	MAR. 1	LOWER RF.	8.33		14.4	4.0	12.8	2.4	12.0	6.0	12.0	4.8	12.0	2.8	12.8	1.6	14.4	4.4	90.4	26.0	13.4	3.7	1.34	0.44		
E-W	X	MAR. 1	WALL	8.00	31.33	9.0	4.3	8.0	7.5	7.0	7.0	7.0	5.7	7.0	2.0	8.0	4.0	9.0	4.0	55.0	34.5	7.9	4.9	1.01	0.61	1.23	0.58
E-W	X	APR. 1	UPPER RF.	15.00		7.6	0.0	18.0	0.0	18.8	0.0	19.0	0.0	18.8	0.0	18.0	0.0	17.6	0.0	127.8	0.0	18.3	0.0	1.22	0.00		
E-W	X	APR. 1	LOWER RF.	8.33		10.0	3.0	10.6	6.8	10.8	10.8	11.0	9.2	0.8	5.2	10.6	3.2	10.0	8.4	73.8	46.6	10.5	6.7	1.26	0.80		
E-W	X	APR. 1	WALL	8.00	31.33	4.0	3.5	4.0	4.0	4.0	3.9	4.0	3.3	4.0	2.5	4.0	1.5	4.0	1.0	28.0	19.8	4.0	2.8	0.50	0.35	1.05	0.30
N-S	B	FEB. 1	ROOF	20.00		36.0	21.0	26.5	0.0	20.0	6.0	16.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	98.5	37.0	14.1	5.3	0.71	0.27		
N-S	B	FEB. 1	ROOF	20.00		0.0	0.0	0.0	0.0	0.0	0.0	16.0	10.0	20.0	6.0	26.5	0.0	36.0	21.0	98.5	37.0	14.1	5.3	0.71	0.27		
N-S	B	FEB. 1	WALL	12.00		27.0	0.0	14.5	6.8	6.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.5	10.5	6.8	1.5	0.57	0.13		
N-S	B	FEB. 1	WALL	12.00	64.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	3.6	14.5	6.8	27.0	0.0	47.5	10.5	6.8	1.5	0.57	0.13	0.65	0.21
N-S	B	MAR. 1	ROOF	20.00		29.0	10.0	24.0	0.0	19.5	7.5	16.0	9.0	3.0	1.5	0.0	0.0	0.0	0.0	91.5	18.0	13.1	2.6	0.66	0.13		
N-S	B	MAR. 1	ROOF	20.00		0.0	0.0	0.0	0.0	3.0	1.5	16.0	9.0	19.5	7.5	24.0	0.0	29.0	0.0	91.5	18.0	13.1	2.6	0.66	0.13		
N-S	B	MAR. 1	WALL	12.00		18.5	0.0	17.0	10.0	4.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	13.5	5.7	1.9	0.48	0.16		
N-S	B	MAR. 1	WALL	12.00	64.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	3.5	17.0	10.0	18.5	0.0	40.0	13.5	5.7	1.9	0.48	0.16	0.59	0.14
N-S	B	APR. 1	ROOF	20.00		25.5	0.0	22.5	1.0	18.0	13.8	16.0	13.0	6.0	5.0	0.0	0.0	0.0	0.0	88.0	32.8	12.6	4.7	0.62	0.24		
N-S	B	APR. 1	ROOF	20.00		0.0	0.0	0.0	0.0	6.0	5.0	16.0	13.0	18.0	13.8	22.5	1.0	25.5	0.0	88.0	32.8	12.6	4.7	0.62	0.24		
N-S	B	APR. 1	WALL	12.00		15.0	5.0	9.0	5.3	4.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	12.5	4.0	1.8	0.33	0.15		
N-S	B	APR. 1	WALL	12.00	64.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	5.3	9.0	5.3	15.0	5.0	28.0	12.5	4.0	1.8	0.33	0.15	0.52	0.20
N-S	G	FEB. 1	ROOF	11.00		22.0	3.5	16.0	0.0	12.0	5.0	10.0	6.0	6.0	3.0	0.0	0.0	0.0	0.0	66.0	17.5	9.4	2.5	0.85	0.23		
N-S	G	FEB. 1	ROOF	11 00	22.00	0.0	0.0	0.0	0.0	6.0	3.0	10.0	6.0	12.0	5.0	16.0	0.0	22.0	3.5	66.0	17.5	9.4	2.5	0.85	0.23	0.85	0.23
N-S	G	MAR. 1	ROOF	11 00		18.0	0.0	15.0	0.0	13.0	8.8	10.0	8.8	7.0	6.0	0.0	0.0	0.0	0.0	63.0	23.5	9.0	3.4	0.62	0.31		
N-S	G	MAR. 1	ROOF	11 00	22.00	0.0	0.0	0.0	0.0	7.0	6.0	10.0	8.8	13.0	8.8	15.0	0.0	18.0	0.0	63.0	23.5	9.0	3.4	0.82	0.31	0.82	0.31
N-S	G	APR. 1	ROOF	11 00		17.0	0.0	14.0	1.0	12.0	3.0	10.0	8.0	8.0	3.8	0.0	0.0	0.0	0.0	61.0	15.8	8.7	2.3	0.79	0.20		
N-S	G	APR. 1	ROOF	11 00	22.00	0.0	0.0	0.0	0.0	8.0	3.8	10.0	8.0	12.0	3.0	14.0	1.0	17.0	0.0	61.0	15.8	8.7	2.3	0.79	0.20	0.79	0.20
N-S	G	FEB. 1	ROOF CONTINUOUS WINDOW	22.00		44.0	7.5	32.0	0.0	24.0	9.0	20.0	11.5	12.0	6.5	0.0	0.0	0.0	0.0	132.0	34.5	18.8	4.9	0.85	0.22		
N-S	G	FEB. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	12.0	6.5	20.0	11.5	24.0	9.0	32.0	0.0	44.0	7.5	132.0	34.5	18.8	4.9	0.85	0.22	0.85	0.22
N-S	G	MAR. 1	ROOF	22.00		36.0	0.0	30.0	0.0	26.0	11.5	20.0	10.0	14.0	6.0	0.0	0.0	0.0	0.0	126.0	27.5	16.0	2.5	0.82	0.11		
N-S	G	MAR. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	14.0	6.0	20.0	10.0	26.0	11.5	30.0	0.0	36.0	0.0	126.0	27.5	18.0	2.5	0.82	0.11	0.82	0.11
N-S	G	APR. 1	ROOF	22.00		34.0	0.0	28.0	0.0	24.0	14.5	20.0	11.8	16.0	10.0	0.0	0.0	0.0	0.0	122.0	37.8	17.4	2.4	0.79	0.11		
N-S	G	APR. 1	ROOF	22.00	44.00	0.0	0.0	0.0	1.5	16.0	10.0	20.0	11.8	24.0	14.0	28.0	1.5	34.0	0.0	122.0	37.8	17.4	2.4	0.79	0.11	0.79	0.11
N-S	W	FEB. 1	ROOF	11.00		13.0	3.6	12.0	0.0	11.0	1.2	10.5	4.5	6.0	2.0	0.0	0.0	0.0	0.0	52.5	11.3	7.5	1.6	0.60	0.15		
N-S	W	FEB. 1	ROOF	11.00	22.00	0.0	0.0	0.0	0.0	6.0	2.0	10.5	4.5	11.0	1.2	12.0	0.0	13.0	3.6	52.5	11.3	7.5	1.6	0.68	0.15	0.68	0.15
N-S	W	MAR. 1	ROOF	11.00		13.0	0.0	12.0	0.0	11.0	7.0	10.5	10.5	8.0	8.0	0.0	0.0	0.0	0.0	54.5	25.5	7.8	3.6	0.71	0.33		
N-S	W	MAR. 1	ROOF	11.00	22.00	0.0	0.0	0.0	0.0	8.0	8.0	10.5	10.5	11.0	7.0	12.0	0.0	13.0	0.0	54.5	25.5	7.8	3.6	0.71	0.33	0.71	0.33
N-S	W	APR. 1	ROOF	11.00		14.0	0.0	12.0	0.0	11.5	4.0	10.5	4.5	10.0	3.5	0.0	0.0	0.0	0.0	58.0	12.0	8.3	1.7	0.76	0.15		
N-S	W	APR. 1	ROOF	11.00	22.00	0.0	0.0	0.0	0.0	10.0	3.5	10.5	4.5	11.5	4.0	12.0	0.0	14.0	0.0	58.0	12.0	8.3	1.7	0.76	0.15	0.76	0.15
N-S	W	FEB. 1	ROOF CONTINUOUS WINDOW	22.00		26.0	8.8	24.0	0.0	22.0	7.5	21.0	13.0	12.0	7.0	0.0	0.0	0.0	0.0	105.0	36.3	15.0	5.2	0.68	0.24		
N-S	W	FEB. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	12.0	7.0	21.0	13.0	22.0	7.5	24.0	0.0	26.0	8.8	105.0	36.3	15.0	5.2	0.68	0.24	0.68	0.24
N-S	W	MAR. 1	ROOF	22.00		26.0	0.0	24.0	0.0	22.0	9.0	21.0	14.0	16.0	10.0	0.0	0.0	0.0	0.0	109.0	33.0	15.6	4.7	0.71	0.21		
N-S	W	MAR. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	16.0	10.0	21.0	14.0	22.0	9.0	24.0	0.0	26.0	0.0	109.0	33.0	15.6	4.7	0.71	0.21	0.71	0.21
N-S	W	APR. 1	ROOF	22.00		28.0	0.0	24.0	0.0	23.0	15.0	21.0	14.0	20.0	12.8	0.0	0.0	0.0	0.0	116.0	42.0	16.6	6.0	0.76	0.27		
N-S	W	APR. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	20.0	12.8	21.0	14.0	23.0	15.0	24.0	0.0	28.0	0.0	116.0	42.0	16.6	6.0	0.76	0.27	0.76	0.27
N-S	X	FEB. 1	UPPER RF.	11.00		18.0	8.0	14.0	0.0	11.2	2.0	9.4	6.8	7.0	4.5	0.0	0.0	0.0	0.0	59.6	21.3	8.5	3.0	0.77	0.27		
N-S	X	FEB. 1	UPPER RF.	11.00		0.0	0.0	0.0	0.0	7.0	4.5	9.4	6.8	11.2	2.0	14.0	0.0	18.0	8.0	59.6	21.3	8.5	3.0	0.77	0.27		
N-S	X	FEB. 1	LOWER RF.	9.00		18.0	0.0	12.8	3.5	9.0	7.2	8.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	47.8	15.5	6.8	2.2	0.75	0.24		
N-S	X	FEB. 1	LOWER RF.	9.00	40.00	0.0	0.0	0.0	0.0	0.0	0.0	8.0	4.8	9.0	7.2	12.8	3.5	18.0	0.0	47.8	15.5	6.8	2.2	0.75	0.24	0.76	0.26
N-S	X	MAR. 1	UPPER RF.	11.00		19.0	2.0	13.0	0.0	11.5	2.2	10.0	7.5	8.0	6.0	0.0	0.0	0.0	0.0	61.5	17.7	8.8	2.5	0.80	0.23		
N-S	X	MAR. 1	UPPER RF.	11.00		0.0	0.0	0.0	0.0	8.0	6.0	10.0	7.5	11.5	2.2	13.0	0.0	19.0	2.0	61.5	17.7	8.8	2.5	0.80	0.23		
N-S	X	MAR. 1	LOWER RF.	9.00		15.2	0.0	11.5	2.0	9.0	3.6	7.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	42.7	8.1	6.1	1.2	0.68	0.13		
N-S	X	MAR. 1	LOWER RF.	9.00	40.00	0.0	0.0	0.0	0.0	0.0	0.0	7.0	2.5	9.0	3.6	11.5	2.0	15.2	0.0	42.7	8.1	6.1	1.2	0.68	0.13	0.74	0.18
N-S	X	APR. 1	UPPER RF.	11.00		15.0	0.0	11.5	0.0	11.3	1.5	10.0	3.2	9.0	3.0	0.0	0.0	0.0	0.0	56.8	7.7	8.1	1.1	0.74	0.10		
N-S	X	APR. 1	UPPER RF.	11.00		0.0	0.0	0.0	0.0	9.0	3.0	10.0	3.2	11.3	1.5	11.5	0.0	15.0	0.0	56.8	7.7	8.1	1.1	0.74	0.10		
N-S	X	APR. 1	LOWER RF.	9.00		14.0	3.8	10.5	7.0	8.5	5.5	6.5	4.2	0.0	0.0	0.0	0.0	0.0	0.0	39.5	20.5	5.6	2.9	0.62	0.32		
N-S	X	APR. 1	LOWER RF.	9.00	40.00	0.0	0.0	0.0	0.0	0.0	0.0	6.5	4.2	8.5	5.5	10.5	7.0	14.0	3.8	39.5	20.5	5.6	2.9	0.62	0.32	0.68	0.20
N-S	X	FEB. 1	ROOF CONTINUOUS WINDOW	22.00		36.0	20.0	27.0	0.0	24.0	2.5	19.5	13.0	14.0	9.0	0.0	0.0	0.0	0.0	120.5	44.5	17.2	6.4	0.78	0.29		
N-S	X	FEB. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	14.0	9.0	19.5	13.0	24.0	2.5	27.0	0.0	36.0	20.0	120.5	44.5	17.2	6.4	0.78	0.29	0.78	0.29
N-S	X	MAR. 1	ROOF	22.00		32.0	0.0	27.0	0.0	22.0	4.5	18.0	11.3	15.0	1.0	0.0	0.0	0.0	0.0	114.0	25.8	16.3	3.7	0.74	0.17		
N-S	X	MAR. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	15.0	10.0	18.0	11.3	22.0	4.5	27.0	0.0	32.0	0.0	114.0	25.8	16.3	3.7	0.74	0.17	0.74	0.17
N-S	X	APR. 1	ROOF	22.00		29.0	0.0	26.0	0.0	22.0	8.0	19.0	10.0	16.0	10.5	0.0	0.0	0.0	0.0	112.0	28.5	16.0	4.1	0.73	0.18		
N-S	X	APR. 1	ROOF	22.00	44.00	0.0	0.0	0.0	0.0	16.0	10.5	19.0	10.0	22.0	8.0	26.0	0.0	29.0	0.0	112.0	28.5	16.0	4.1	0.73	0.18	0.73	0.18
NE-SW	G	FEB. 1	UPPER † RF.	15.00		0.0	0.0	0.0	0.0	12.5	9.5	20.5	5.5	18.5	8.0	16.0	0.0	0.0	0.0	67.0	23.0	9.6	3.3	0.64	0.22		
NE-SW	G	FEB. 1	LOWER † RF.	8.00		19.0	7.0	14.5	0.0	12.0	0.0	11.5	2.5	10.5	7.0	9.0	3.0	7.0	5.5	83.0	25.0	11.9	3.6	1.45	0.45		
NE-SW	G	FEB. 1	WALL †	8.00	31.00	24.0	3.0	16.0	5.5	12.5	4.0	9.5	3.5	7.0	4.0	4.0	3.0	0.0	0.0	73.0	23.0	10.4	3.3	1.30	0.41	1.03	0.33
NE-SW	G	MAR. 1	UPPER † RF.	15.00		0.0	0.0	14.5	4.0	20.0	13.2	18.5	5.5	17.0	0.0	14.5	0.0	12.5	1.0	97.0	23.7	13.9	3.4	0.93	0.23		
NE-SW	G	MAR. 1	LOWER † RF.	8.00		14.5	0.0	12.5	0.0	11.0	1.0	10.0	4.5	9.5	8.5	8.0	7.0	3.0	0.5	68.5	21.5	9.8	3.1	1.22	0.39		
NE-SW	G	MAR. 1	WALL †	8.00	31.00	16.5	8.8	12.0	7.5	10.0	3.8	6.0	1.5	4.0	1.0	0.0	0.0	0.0	0.0	48.5	22.5	6.9	3.2	0.86	0.40	0.99	0.31
NE-SW	G	APR. 1	UPPER † RF.	15.00		20.5	15.0	19.5	10.5	17.5	1.0	16.5	0.0	15.5	0.0	14.0	0.0	11.0	1.0	114.0	27.0	16.3	3.9	1.09	0.26		
NE-SW	G	APR. 1	LOWER † RF.	8.00		12.0	1.0	10.5	4.5	9.5	3.0	8.0	2.0	8.0	2.5	7.0	4.5	0.0	0.0	55.0	17.0	7.9	2.4	0.99	0.30		
NE-SW	G	APR. 1	WALL †	8.00	31.00	10.5	10.5	8.0	6.0	6.5	4.0	4.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	31.0	23.0	4.4	3.3	0.55	0.41	0.92	0.31
NE-SW	G	FEB. 1	S. E. ‡ RF.	11.00		21.0	17.0	19.5	0.0	17.0	0.0	15.5	0.0	14.0	0.0	12.5	3.0	10.5	7.0	110.0	27.0	15.5	3.9	1.41	0.35		
NE-SW	G	FEB. 1	N. W. ‡ RF.	11.00	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	1.5	10.5	6.0	16.0	7.5	2.3	1.1	0.21	0.10	0.81	0.23
NE-SW	G	MAR. 1	S. E. ‡ RF.	11.00		20.0	2.5	17.0	0.0	15.0	0.0	14.0	0.0	13.0	5.5	11.0	8.0	9.0	4.0	99.0	20.0	14.1	2.9	1.28	0.26		
NE-SW	G	MAR. 1	N. W. ‡ RF.	11.00	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3.0	9.0	7.0	11.0	6.0	23.0	16.0	3.3	2.3	0.30	0.21	0.79	0.23
NE-SW	G	APR. 1	S. E. ‡ RF.	11.00		15.0	0.0	14.5	0.0	14.0	1.0	12.5	1.5	12.0	6.0	10.5	10.0	9.0	8.0	87.0	26.0	12.4	3.7	1.13	0.34		
NE-SW	G	APR. 1	N. W. ‡ RF.	11.00	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	5.0	10.5	9.0	12.0	10.0	31.0	15.0	4.4	2.1	0.40	0.19	0.73	0.27
NE-SW *	G	FEB. 1	UPPER † RF.	15.00		0.0	0.0	0.0	0.0	12.5	6.0	20.5	19.0	18.5	1.0	16.0	0.0	0.0	0.0	67.0	26.0	9.6	3.7	0.64	0.25		
NE-SW *	G	FEB. 1	LOWER † RF.	8.00		19.0	3.0	14.5	0.0	12.0	0.0	11.5	1.0	10.5	4.0	9.0	7.5	7.0	3.0	83.0	18.5	11.9	2.6	1.45	0.32		
NE-SW *	G	FEB. 1	WALL †	8.00	31.00	24.0	2.5	16.0	10.0	12.5	11.0	9.5	7.0	7.0	2.0	4.0	1.0	0.0	0.0	73.0	33.5	10.4	4.8	1.30	0.60	1.03	0.36
NE-SW *	G	MAR. 1	UPPER † RF.	15.00		0.0	0.0	14.5	14.0	20.0	5.0	18.5	3.0	17.0	0.0	14.5	0.0	12.5	1.5	97.0	23.5	13.9	3.3	0.93	0.22		
NE-SW *	G	MAR. 1	LOWER † RF.	8.00		14.5	0.0	12.5	0.0	11.0	2.0	10.0	4.0	9.5	2.0	8.0	4.0	3.0	1.5	68.5	13.5	9.8	1.9	1.22	0.24		
NE-SW *	G	MAR. 1	WALL †	8.00	31.00	16.5	5.0	12.0	9.0	10.0	10.0	6.0	6.0	4.0	3.0	0.0	0.0	0.0	0.0	48.5	33.0	6.9	4.7	0.86	0.59	0.99	0.32
NE-SW *	G	APR. 1	UPPER † RF.	15.00		20.5	5.0	19.5	9.0	17.5	2.0	16.5	0.0	15.5	0.0	14.0	0.0	11.0	4.0	114.0	20.0	16.3	2.9	1.09	0.19		
NE-SW *	G	APR. 1	LOWER † RF.	8.00		12.0	0.0	10.5	4.5	9.5	9.5	8.0	7.0	8.0	5.0	7.0	2.0	0.0	0.0	55.0	28.0	7.9	4.0	0.99	0.50		
NE-SW *	G	APR. 1	WALL †	8.00	31.00	10.5	5.0	8.0	6.0	6.5	4.0	4.0	4.0	2.0	2.0	0.0	0.0	0.0	0.0	31.0	21.0	4.4	3.0	0.55	0.38	0.92	0.32
NE-SW *	G	FEB. 1	S. E. ‡ RF.	11.00		21.0	13.0	19.5	0.0	17.0	0.0	15.5	0.0	14.0	0.0	12.5	6.0	10.5	8.0	110.0	27.0	15.5	3.9	1.41	0.35		
NE-SW *	G	FEB. 1	N. W. ‡ RF.	11.00	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	2.5	10.5	8.0	16.0	10.5	2.3	1.5	0.21	0.14	0.81	0.25
NE-SW *	G	MAR. 1	S. E. ‡ RF.	11.00		20.0	1.0	17.0	0.0	15.0	0.0	14.0	0.0	13.0	1.5	11.0	8.0	9.0	7.0	99.0	17.5	14.1	2.5	1.28	0.23		
NE-SW *	G	MAR. 1	N. W. ‡ RF.	11.00	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	1.0	9.0	7.0	11.0	7.0	23.0	15.0	3.3	2.1	0.30	0.19	0.79	0.21
NE-SW *	G	APR. 1	S. E. ‡ RF.	11.00		15.0	0.0	14.5	0.0	14.0	3.0	12.5	6.0	12.0	5.0	10.5	2.5	9.0	5.0	87.0	21.5	12.4	3.1	1.13	0.28		
NE-SW *	G	APR. 1	N. W. ‡ RF.	11.00	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	4.0	10.5	2.5	12.0	7.5	31.0	14.0	4.4	2.0	0.40	0.18	0.73	0.23

* BED TO N.W. OF PEN. † E.W. TYPE WINDOWS. ‡ N.S. TYPE WINDOWS.

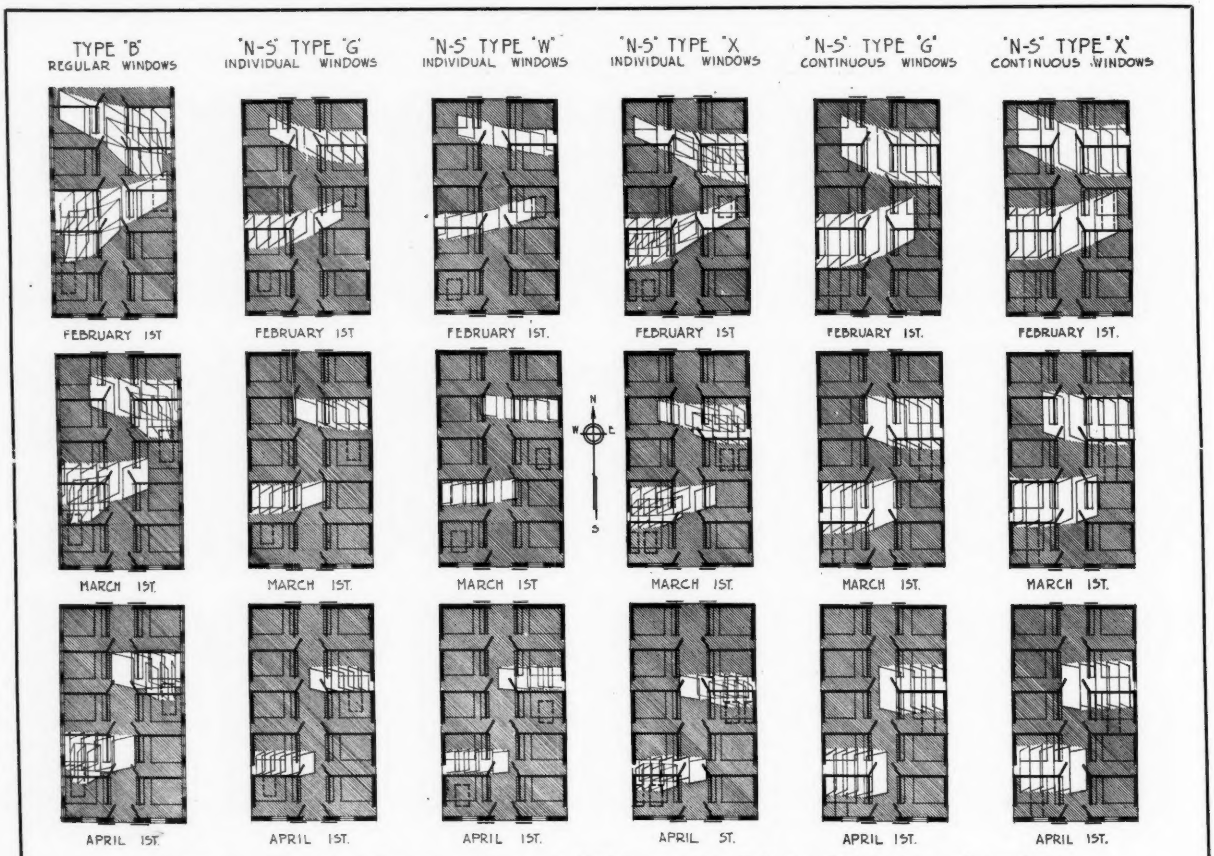


Figure 5. Chart showing sun patterns of all N-S types for Feb. 1st, March 1st, and April 1st

designs strike directly across the beds and give excellent sunshine on the beds. One pattern follows another along the north row of pens in such a way that the warmth which accumulates will keep the beds dry and comfortable.

The nearness of the windows to the beds in the pens on the south side of the building makes their sun patterns move slowly and allows the accumulation of heat. On April 1 when the sun is higher the sun patterns have begun to leave the north row of pens and move into the alley, and the patterns in the south row of pens are greatly diminished. The sunlight, however, by this time of the year has become very much warmer and the necessity for sunlight within the building greatly lessened since the building will be kept open and the hogs will be free to run in the sunlight outside. By midsummer when the sun's rays become intense the sun patterns in the east-west types will have practically left the beds and the building can be used for shade. This is a desirable consideration which is not found in the north-south types. The fact that each window in the east-west types produces sun patterns for the entire day is also important.

The concentration of the sun's rays upon the beds results in less sunlight falling upon other parts of the building, particularly in east-west types, and reduces that upon the central feed alley materially. This is probably unimportant as the animals do not occupy nor litter this part of the building, and it is easily swept or washed out.

The patterns for the various north-south types are given in Fig. 5. This figure also shows types G and X arranged with continuous roof windows. Sun patterns are given for February 1, March 1, and April 1. Because of the confusion that would arise due to the overlapping of the sun patterns which would be produced by the windows of pens directly on opposite sides of the central aisle, the windows for the pen in the southwest corner and the one in the middle of the east side were used to produce the patterns in this plate.

A comparison of Tables II and III show the effect of this. The last two columns in these tables represent the efficiency for the floor and bed respectively. The figures obtained for all east-west types taken together and also those for all north-south types run close enough together that their averages may be considered as a safe basis for comparison. The average efficiency for the entire spring farrowing period for east-west types is 1.08 for the floor as compared with 0.73 for the north-south types. The comparative figures for the beds are 0.45 and 0.21, respectively. That is, on the average a square foot of glass in a north-south type will admit to the floor of the hog house 68 per cent of the amount admitted by east-west building and only 47 per cent as much to the bed.

The building giving the sun patterns shown in Fig. 2 is similar to type X but the windows are placed at the ridge and the lower slope of the roof is too steep. It is among the better than average buildings in general use. The windows are too high at the ridge of the roof. The total glass area is smaller than most of the types shown in Fig. 3, but this should tend to increase rather than decrease the efficiency rating as it is easier to keep a larger percentage of a small pattern on the bed than a large pattern. One square foot of glass on the average in this building will furnish 0.575 square feet of sunshine to the floor and 0.135 to the bed on March 1, as compared with 1.31 and 0.72, which are the averages on that date, for all the east-west types and 0.73 and 0.21 for all north-south types shown in Fig. 4. That is,

it will admit to the floor and bed, respectively, 44 per cent and 19 per cent as much as the east-west types, and 79 per cent and 64 per cent as much as the suggested standard north-south types. This indicates that by the careful design of the building 20 per cent more sunlight can be thrown upon the floor and 33 per cent more upon the beds of a north-south hog house, and also that more than twice as much sunlight per square foot of glass may be obtained on the floor, and more than four times as much upon the bed of a well-designed east-west type of hog house than is obtained in most of the north-south hog houses being erected at the present time.

It is sometimes desirable because of the lay of the land, existing buildings or other improvements about a farmstead, or because of the choice of a breeder, to run a hog house in a diagonal position with reference to the points of the compass. Fig. 6 shows the sun patterns made by a type G building set in this position. The three drawings on the left in this plate show sun patterns made by the window arrangement of an east-west building with the windows facing to the south-east. The three drawings to the right are for a north-south window arrangement of type G with separated windows. Measurements of the sun patterns on the bed were made both with the bed to the north-east and to the south-west of the pen. Table IV shows no particular preference for either position of the bed. It indicates that the window arrangement of the east-west type is more desirable than the north-south window arrangement for building placed in this position. The average efficiency of the type placed diagonally is between the averages of the east-west and the north-south types, the figures being:

	Floor	Bed
East-west types..........................	1.08	0.45
Diagonal, E-W windows..................	0.98	0.32
Diagonal, N-S windows..................	0.79	0.23
North-South types.......................	0.73	0.21

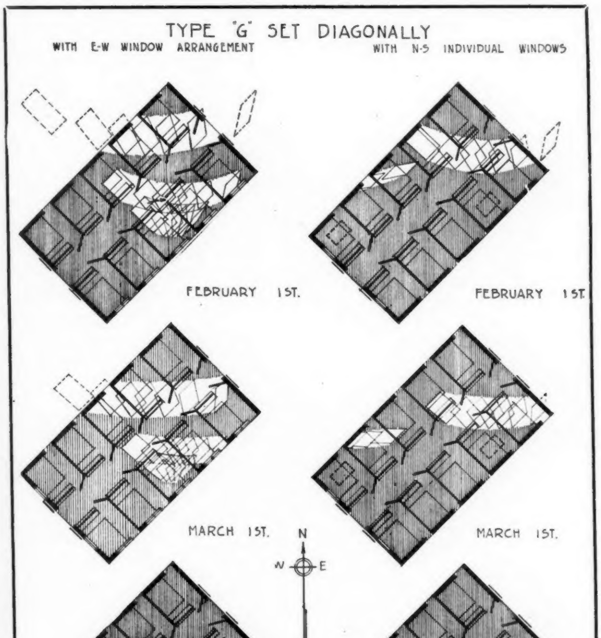


Figure 6. Chart of sun patterns for NE-SW type G

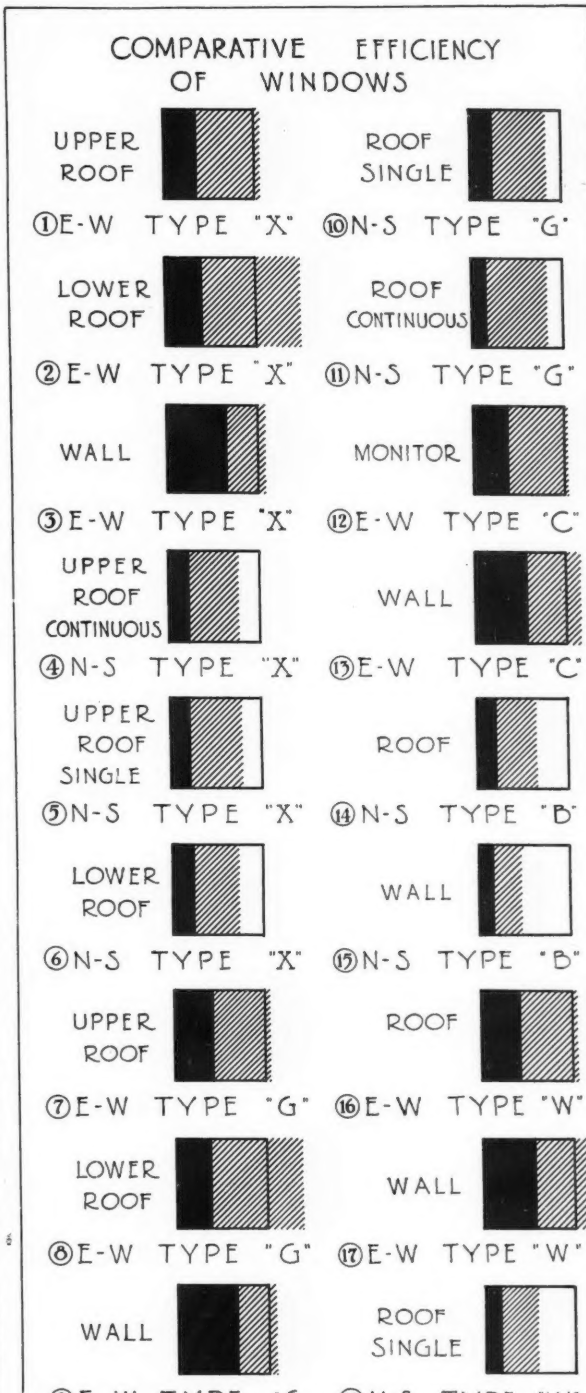


Figure 7. Chart of comparative efficiencies of windows

The figures would be the same as those given in Table IV if the building were run in a northwest-southeast direction, because the relation between the position of the sun and parts of the building would correspond exactly to their relation in the other position.

The window locations have an important bearing upon the effectiveness of the sunshine in the buildings and efficiencies of the various types. When a window is far away from the floor or bed the movement of its pattern across the floor is correspondingly rapid and less warmth will accumulate at any point unless it is followed up soon by another pattern. This occurs in the east-west buildings but not in the north-south types. When the window is near the floor or bed the movement is much less from hour to hour and also there is less seasonal change in the position of the patterns. These facts justify the wall windows shown in the south wall of some of the east-west types. These windows should be guarded with wire mesh or be made of heavy wire glass.

In Table 2 the efficiency is in an inverse ratio to the glass area. While there are other features than the glass area which should be taken into consideration in accounting for this, it is logical that there should be a decreasing efficiency with respect to concentrating the sunshine upon the bed when the glass area and, consequently, the size of the patterns is increased. Investigations made by increasing the glass area in some of the types have shown that there would be a slight decrease in the efficiency in such cases.

Fig. 7 is a graphic chart based on the figures in Table I. It gives the comparative efficiencies of the various windows in the different types. Here the efficiencies are represented on the square-foot basis, the black area representing the average amount of sunshine which a square foot of glass in a particular window will throw on the bed during the entire day. The shaded area shows the additional amount of sunshine which that square foot of glass will throw upon the floor, outside of the bed, during the day. The heavy outline which includes the black area in each figure represents the outline of one square foot and is for convenience in comparing areas. These graphs show that the wall windows will average fifty per cent more sunshine on the beds than is shown by other windows. Refer to graphs numbered 3, 9, 13, and 17. Graphs numbered 2 and 8 represent lower roof windows in east-west types and show about the same amount of sunlight upon the beds of these types, but considerably more upon the floor than graphs 1 and 7, representing the upper roof windows.

Graphs numbered 4, 5, 6, 10, 11, 14, 15, 18, and 19 in Fig. 7 representing the windows in the north-south types. Their average efficiency is much lower than the windows of the east-west types. These windows were all located along the roof in the position which would give the best sunlight into the beds on March 1. Sometimes this throws the window over one side of the pen and sometimes the other. When properly set for March 1 sunshine upon the beds, however, the February 1 and March 1 patterns for these windows fall upon the north or south side of the nest owing to the change in the sun's altitude. Generally the windows over one pen, because of the slant of the sun's rays, throw their patterns into the next pen to the north. Readings made for the north-south types indicate that the amount of sunshine thrown into the pens is about the same for the hottest as it is in the coldest months.

Table III shows very little difference in efficiency between the north-south types which have individual windows and those which have continuous windows. It would appear then that in the north-south hog house the amount of sunshine which a breeder wishes to get into the building would determine the kind of windows to use.

The efficiency of the various types with reference to the amount of sunlight thrown on the beds indicates a less favorable condition than that which actually exists owing to the fact that the beds were assumed to be only about five by six feet in size and there will be a considerable amount of warm sunshine thrown into the pen where the sow or swine can use it although it is not actually on the bed. Sometimes the bed covers the entire pen floor. The use of the combined figures for both the efficiency of the sunshine on the bed and over the entire floor will give a reliable idea of results.

Fig. 8 gives a graphic comparison of the glass areas and the areas of sunshine for the entire floor and for the bed for all standard types and window arrangements. The black line represents glass area. The shaded and open lines repre-

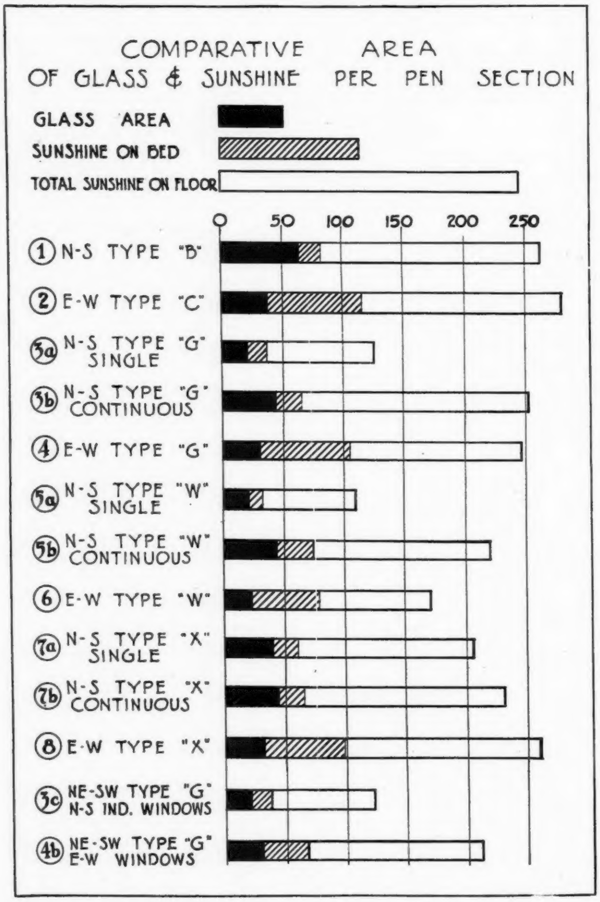


Figure 8. Chart of comparative amounts of glass and total sunshine

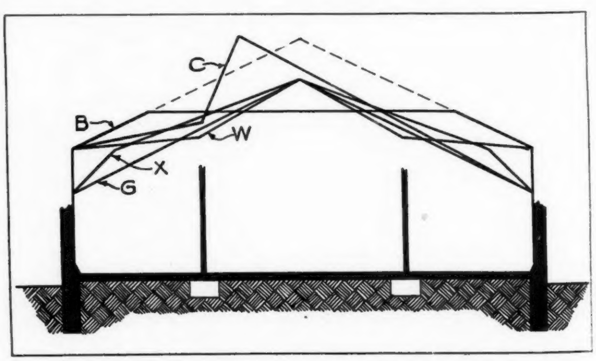


Figure 9. Comparative cross sections of types

sent respectively sunshine on the bed and on the floor in proportion to the relative areas.

A general summary of types B, C, G, W, and X with the various window arrangements is given in Table V. The cubic feet of air, and the roof, wall, and glass exposure per pen section are given for the sake of comparison in addition to figures on sunshine efficiency. Fig. 9 shows comparative cross sections.

The following conclusions may be drawn from the foregoing study:

1. The hog house properly designed and running east and west will admit twice as much sunlight per square foot of glass, to the beds, as the hog house running north and south.
2. The windows will be less exposed to cold winter winds.
3. The movement of the patterns through the building favors the accumulation of more heat on the nests in east-west types.
4. The east-west building offers better summer shade on the beds.
5. The arrangement of windows in the east-west types should be used when the building is run diagonally with respect to the compass points.
6. Wall windows are justified in east-west buildings because of their high efficiency.
7. The closer the windows can be brought to the beds the greater will be their efficiencies from the standpoints of both the concentration of warmth and control of the position of the sun pattern.

Levelling Device for Tractors Working on Hillsides

By J. C. Wooley

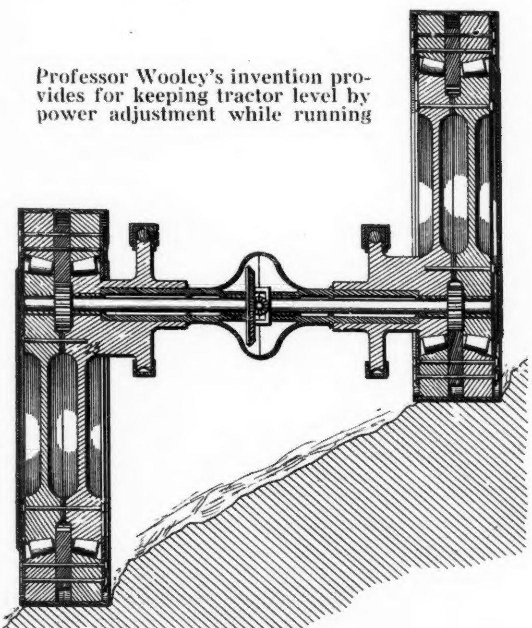
Mem. A.S.A.E. Professor of Agricultural Engineering, University of Missouri

THE surprising thing to the individual as he first visits the Pacific northwest is the topography of the land. Hilly land has usually meant unproductive and unprofitable farms to him. In the leading wheat areas of Idaho, Washington, and Oregon the land lays in long rolling hills with the long way to the southwest and northwest. These productive hills have been built up at the expense of the land to the southwest. Each season finds a new coating of fertility spread over them from the same source. The flat lands are not so productive and, consequently, not so valuable as these hillsides.

The farms are laid out whenever possible so that one man will own a hill. He farms this hill by following around the contour. It would not be practical to farm it in any other way. The slope of these hills varies from ten to as high as fifty per cent.

If a useful machine can be made to operate with such side grades it will be accepted by the ranches of this region for they are great users of machinery and power. Combined harvesters are operated on these hills where one has to see to believe. These machines are equipped with levelling devices and with a long cutter bar which extends up the hill, helping materially to stabilize the machine.

Professor Wooley's invention provides for keeping tractor level by power adjustment while running



The tractor as it is designed today meets with the following difficulties on these hillsides: First, too high a center of gravity; second, loss of traction on the uphill driver; third, end thrust on wheels and bearings; and, fourth, improper oil level in the crankcase of the motor.

The tracklaying type of tractor does not meet with the first objection, although the writer has seen a tractor of this type rolling down one of the steep hillsides in the State of Washington.

The second objection is not so noticeable as with the wheel type of machine.

Observations were made on several hillside tests and noticeable lack of traction on the uphill side was the result on all grades above fifteen per cent. Tractive power is due very largely to weight, and as the machine is tipped over, the difference in traction is very noticeable.

The end thrust is not so great in this type of machine, but nevertheless must be reckoned with in design.

Where a machine is required to run continually on grades of from 10 to 40 per cent the lubrication of the motor may be seriously interfered with. In some models the scoop pans are submerged with oil to insure lubrication, while in others the lower cylinder is flooded and the upper bearings dry. Continued operation without proper lubrication would be unprofitable.

The levelling device shown was designed (and patented) by the writer to overcome these difficulties in the wheel-type machines.

The tractor is tilted by turning the eccentric bearings in opposite directions centering about the internal-drive pinions. Thus the center of gravity is not raised or lowered and the weight remains equal on the drivers.

The eccentric bearings are turned by right and left-hand worm gears operated through an auxiliary friction transmission. Either direction may be secured and consequently the tractor may be tilted either way.

The two worm gears tend to hold the tractor in any position until changed through the transmission.

By keeping the tractor level at all times the danger of overturning is overcome, the traction remains equal from each driver, end thrust is eliminated, and the motor, whether placed lengthwise or crosswise, will have the proper supply of oil at all times.

Farm Building Ventilation and Some Related Factors*

By W. B. Clarkson

Mem. A.S.A.E. Director of Research and Extension, King Ventilating Company. Chairman, A.S.A.E. Subcommittee on Farm Building Ventilation

AS AN introduction to the relation which ventilation bears to the whole subject of farm structures, it seems desirable to describe the conditions which led to a study of this question. The greater part of the work that has been done on the ventilation of farm buildings has been done within the past twenty years. During this time the most remarkable advances have been made in recognizing and in solving the problems which the farmer is forced to overcome in order to obtain sanitary conditions in his barn.

The conditions which led to the study of ventilation and building construction in order to obtain sanitary conditions in farm buildings were very practical difficulties, and they are still present in a large number of the animal shelters on the farms of this country.

When one went into a barn filled with animals which was not ventilated the sensation was very unpleasant. The air of the room was foul smelling and oppressive because of its dampness; the floors were filthy and unsanitary; the walls were damp and covered with frost or moisture, and the temperature conditions were very uneven.

When the door of such a barn was opened the foul, damp air rushed out, and because the outside air was colder a cloud of steam was formed by the condensation. This at once suggested that a circulation of air could be used to do away with some of the foul conditions in the barn.

The problem with which we have to deal is the removal of these bad conditions. Ventilation is the principal factor in the removal of foul conditions. Yet the assumption should not be made that ventilation is the complete remedy for all of these bad conditions.

While the subject of this discussion is primarily the ventilation of farm buildings, the fact that other factors are in themselves related to ventilation in the obtaining of sanitary conditions forces us to study them in connection with ventilation.

It was mentioned above that one of the conditions in the barn was the filthy condition of the floor. This problem has been worked on a great deal, and now the flooring of animal shelters is considered a success. A smooth, hard, solid, and nonabsorbent surface has been found necessary and these are the kind of floors that are being built in modern dairy barns. However, the obtaining of a sanitary floor is not apart from ventilation because, in order that a floor may be dry, the air must be relieved of the excessive moisture thrown into it by the stock.

Because of the relation of the animal life within the building and the plan and construction of the building itself to the conditions of sanitation, the work of your committee in studying farm building ventilation has divided itself into at least four separate fields. These were discussed in the last several annual reports of this committee, but it seems worth while now to divide them more carefully and to give the report of our progress along these separate lines. These as they appear to us are:

1. Relation between the animal life and the condition of the stable air
2. Climatic conditions which affect ventilation
3. The relation of barn construction to sanitation
4. Design of ventilating apparatus

The information that has been published within the past year on this subject is one of the greatest marks of progress that your committee has been able to report for the past several years. "Some Fundamentals of Stable Ventilation," by Henry Prentiss Armsby and Max Kriss, director and associate, respectively, of the Institute of Animal Nutrition, Pennsylvania State College, has furnished definite data showing the production of heat carbon dioxide, and moisture by typical farm animals. (This article was published in the June number of the "Journal of Agricultural Research" of the U. S. Department of Agriculture, and reprinted in the July and August, 1921, numbers of AGRICULTURAL ENGINEERING.) This work was undertaken upon the initiative and with the cooperation of the chairman of this committee, and the results are practical in every way for use in our study of farm-building ventilation and also in the application of ventilation to the individual barn. Without reviewing the subject matter of the article further, it seems advisable to discuss in detail the application of this most valuable data.

The most fundamental basis for judging the sanitation of a barn found so far is the use of the animal heat. The data presented by Dr. Armsby enables us to estimate within very reasonable limits the amount of heat produced by a herd of cattle or other animals that are housed in a stable. This is done by computing the maintenance ration for animals of the size that are in the barn and then adding the heat due to the food consumed in excess to that required for maintenance.

HEAT USED TO KEEP BARN AT PROPER TEMPERATURE

The question which confronts the agricultural engineer is, What can be accomplished with this heat? The answer to this question is that it must, under practical circumstances, keep the barn at a comfortable degree of temperature and provide a motive power for a sufficient amount of air circulation to keep the stable air pure.

Under the heading of the relation of the animal life to the stable air conditions, the question of the most desirable temperature of the stable air for each of the farm animals immediately presents itself. We must admit at the outset that there is a great deal of further research work to be done on this subject. Yet there are certain sources of information available now and it is necessary for us as engineers to use these until further research has been made by those who are interested primarily in animal husbandry.

From a theoretical and pure research standpoint the information bearing on this subject is that for each animal there is a critical temperature at which the production of heat is minimum and at which the utilization of feed for maintenance and production is optimum. It is not known exactly what is the critical temperature for all of the several

*One section of the report of the Subcommittee on Farm Building Ventilation to be presented at the fifteenth annual meeting of the American Society of Agricultural Engineers to be held in Chicago, December 27, 28, and 29, 1921.

farm animals and this is another point upon which we have still to wait further information.

However, we are not wanting for a great deal of practical information as to the desirable temperature for the stable air. In order to get the information that is in the hands of the animal husbandry men of today into tangible form, the chairman of this committee sent out during the past year a questionnaire to the animal husbandry departments of several state agricultural colleges of this country and Canada. The questions were on the desirable temperature for dairy barns. The replies came back almost uniformly recommending a temperature of from 40 to 45 degrees in the northern part of the country and from 45 to 50 degrees in the central portion of the United States. The replies came from about thirty of the heads of animal husbandry departments, and can be taken as a sound, practical index of the opinion on the subject today.

It has also been the observation of this committee that from a practical standpoint it is possible to maintain this temperature with a good amount of circulation.

Still another question that arises is the purity of barn air which should be maintained. As stated by Prof. F. H. King, "The real problem with which we have finally to deal is how nearly can we maintain the air of dwellings and stables at the normal out-of-door fresh air purity with practicable economy." This Society has already adopted a standard circulation of air as desirable, but it should not be lost sight of that fresh air is very vital to the health and production of the animals and a larger circulation may still be practicable in some cases. For this reason we should not lose sight of the fact that there is still a great need of research to determine the practical requirements for ventilation.

The other measure which we have at present of the ventilation of the stable is the amount of moisture present in the air of the stable room compared with the moisture in the outside air. Insofar as this is connected with the relation of animal life to the stable air conditions it is through the amount of moisture produced by the animals themselves and with the effect of this moisture on the health and production when it is not removed by the animals has been covered very thoroughly by Dr. Armsby in the article above referred to. As far as we know the effect of this excessive moisture on the health and production of the animals has not been studied from a purely scientific standpoint, and here again the results that we are able to find are purely from a practical standpoint.

It has been the experience of many livestock owners that the excessive moisture of the stable air is detrimental to the keeping of the coats of the animals in good shape as the excessive moisture causes the coats to shed prematurely. It has also been the experience of dairymen that animals which partially shed in this manner and which had been housed in excessively warm stables in the fall fell off a great deal in production when a cold snap came.

The factors to be considered in regard to climate when studying the ventilation of barns are (1) the minimum temperature likely to be experienced, (2) the temperature at which the ventilating system will be called upon to operate during the greater portion of the winter season, and (3) the temperature conditions which will require the minimum capacity of the ventilating system.

It is at once evident that the division of the country into zones with respect to similar climatic conditions enables us to make a close estimate of these conditions to apply to an animal shelter in any particular part of the country. The United States Weather Bureau has prepared maps, some of them at the request of the chairman of this committee, which show us definitely the temperature conditions that can be expected in the different climates.

The third question, as to the maximum outside temperature at which the system will be expected to operate, is not so easily answered. It has been definitely found that many farmers keep their animals in the barn in the spring when the outside temperature is at least 50 degrees. This means that the capacity of the system must be very large in order to remove the excessive heat and moisture.

The relation of this condition to the ventilation of the building comes under the head of the design of ventilating apparatus, rather than the relation of the climatic conditions. It, therefore, seems best to leave the subject of climatic conditions with these few statements of general summary.

Reducing Production Costs

FOR practical purposes the only important point where costs per acre can be cut down appreciably is in plowing and the other operations of seedbed preparation, and in the cultivation of intertilled crops. The important point is that to cut down the cost per acre by slighting any of these operations is the worst kind of economy, for the reason that the yield is affected seriously, while the other costs continue without appreciable decrease. The economical thing to do is to expend enough both of power and man labor to soil preparation to assure maximum crops, thereby covering not only the increased cost of preparation, but also yielding the maximum return of the fixed charges.

This is not to be taken as meaning that good plowing and tillage should be done without regard to the cost of these operations. On the other hand, the cost should be cut to a minimum consistent with the desired quality and timeliness of the work.

Any consideration of power costs will be misleading if they are calculated by the acre. The only way in which power costs can be of assistance in making plans is by having them figured out in cost per bushel of crop produced. This is only another way of saying that the cost of power is important in relation to the value of that power. A five-inch job of plowing in October undoubtedly is cheaper by the acre than seven-inch plowing in July, but in relation to the wheat crop the following year the five-inch October job usually will be found much more expensive. The same principle applies to other operations and other crops.

Other things which must be considered in connection with seedbed management are conservation of moisture, the control of capillarity and the liberation of plant food. Sometimes conservation of moisture will dictate pulling a disk harrow behind the binder; sometimes it means early summer plowing and the maintenance of a mulch; again it may mean adequate summer fallow treatment. In any case an abundance of power to do the work in just the right way and at just the right time will have a controlling influence on the yield of the following crop.

Examples might be multiplied showing how an abundance of power applied at just the right time with plow and harrow will exterminate weeds which otherwise would reduce both the yield and grade of the following year's crop; how plenty of power speeds up haying and harvesting so that a maximum amount of the crops is secured in the best possible condition; and other ways in which ample power which can be used without regard to heat and other adverse conditions and which involves no expense when not at work increases farm income, by reducing cost per unit of product, and at the same time increasing the volume of production on which a profit, even though a modest profit, may be made.

Possibilities in Farm Equipment Standardization*

By E. A. White

President, American Society of Agricultural Engineers.
Technical editor, "Farm Implement News"

STANDARDIZATION is not a new subject to members of the farm-operating-equipment industry. At least as far back as 1913 your association was giving serious consideration to standardization, and in some form or other it has been constantly before the farm-operating-equipment industry since that date. During the late war the standardization of farm implements and machines received a marked stimulus especially as related to the elimination of sizes, styles, and types. In fact, developments during this period were so rapid and far-reaching that the industry has not yet completely digested the meal which it so willingly helped to prepare.

In the past the subject of standardization has occupied conspicuous places on the programs of your departmental gatherings and annual meetings. The character and ability of the men who have previously been selected to discuss this subject vouch for its importance and guarantee that it has been discussed in an able manner. These facts are substantiated by the action which has been taken at various times by various departments of your organization.

So there can be no doubt but what this industry is definitely committed to standardization work and will continue to solve the various problems as they are presented.

NATIONAL ASSOCIATION OF FARM EQUIPMENT MANUFACTURERS

Thus the desirability of standardizing along constructive lines is recognized. It is freely admitted that this avenue represents one outlet for relieving present conditions and insuring greater stability to meet future contingencies.

It is an interesting fact that during all this previous discussion no one has formulated a definition for standardization in the farm-operating-equipment industry which has been generally accepted. It will not be conceded that this is impossible, but instead of attempting to develop such a definition it seems vastly more important to proceed to the discussion of lines along which standardization work may logically develop and let time develop the definition. In spite of the large amount of work already done none of us know exactly what future standardization work may develop. It is not a subject whose limits are definitely fixed but appears to be capable of almost indefinite expansion changing with new developments in both the economic and mechanical fields. It is a subject which should be approached with an open mind but with a determination to keep it within practical bounds.

Standardization has a direct bearing upon the manufacture, sale, and use of farm-operating equipment. Therefore, what is done or what is not done is certain to have far-reaching effects not only upon those directly concerned with manufacture, sale, and use of farm equipment but upon our national development as well. To some this may appear to be stretching the point to make a case for standardization, but let us, briefly, look at the facts in the case. The effects of the development and use of farm-operating equipment upon our agricultural development have been often and ably presented. Only last year at your annual convention Floyd R. Todd presented a most convincing summary of this subject, but what has been implied, namely, that the development of American farm-operating equipment has had just as marked effects upon national, yes, even international, developments has not been sufficiently emphasized. I am one of those who would, consciously or unconsciously, magnify the importance of this industry in comparison with other essential industries. All are necessary for our national development but I am convinced that the true relation of the farm-operating-equipment industry to our national development has not been fully realized by the general public.

To insure a well rounded natural development not only of our agriculture but of our industries, transportation, commerce, arts, sciences and professions, in fact, all those larger spheres which contribute to our national development it is necessary that we have food, clothing and shelter at reasonable prices to the consumer but produced at a profit by those who till the soil. I am not one of those who views with alarm our relative decrease in rural population. Insofar as the youth of the land are being drawn to the centers of population because of more remunerative employment, better living and social conditions, the situation has a serious aspect, but if the thirty-five per cent of our population working the farms can maintain our per capita food supply, leaving the other sixty-five per cent to be employed gainfully in industries, commerce, arts, sciences, professions, etc., it means that we are assured of a more rapid natural development than would be the case if ninety-five per cent of our population was required to produce the raw materials for food, clothing and shelter as in 1820. The development of modern farm machinery has made this change possible and, therefore, its manufacture, sale, and use bears a most important relation to our national development.

In a very direct manner the implement industry is one of the foundation pillars on which the national superstructure is built. Therefore, standardization in this industry is justly of national concern, and it is reasonable to expect that the institutions so wisely provided by governmental action to foster agricultural and industrial developments will be increasingly interested in this subject.

COST OF PRODUCTION IMPORTANT FACTOR

In considering this subject in its broadest aspects it is desirable to get some information regarding the relative cost of farm equipment to the farmer. The value of farm crops as given by the United States Department of Agriculture for 1920 was $9,165,348,000. For the same year the value of farm-equipment sales by manufacturers to dealers was reported as $471,442,000. The above figures do not represent the entire farm income for no account was taken of poultry, livestock, and dairy products. Undoubtedly feeding a large part of these crops brought an income over and above their market values, but without making any allowance for this increase or adding the dealer's commission it appears that the value of the farm equipment was only five per cent of the value of the crops.

Looking at this situation from the cost of production standpoint throws a more illuminating light on the problem. Prof. G. F. Warren, of Cornell University, and Prof. F. W.

*An address delivered at the twenty-eighth annual convention of the National Association of Farm Equipment Manufacturers.

Peck, of the University of Minnesota, are recognized as among the leading authorities on farm management. These two men have directed extensive investigations into the costs of producing farm crops. For the purposes of this discussion we are not so much interested in the total cost figures as the percentages of the total costs to be charged against certain items, especially man labor, power and machinery. Apportioning the costs on this basis the figures given in Table I are secured. The New York studies covered the years 1912 and 1913; those conducted in Minnesota the years 1913-1917, inclusive. With the exception of the operations requiring belt-driven machines no mechanical motors were used on the farms included in the studies from which these data were compiled. Therefore, the large percentage of the power costs are reported as horse labor. With the increasing use of the mechanical motor there may develop a tendency to classify the power and machine costs under one head. This would be a mistake for an intelligent analysis of production costs demands that a distinction be made between costs of producing power and other machine costs. These are two distinct problems. In studying the data presented it is found that the charges, man labor, power, and machinery, constitute from 31 to 69.5 per cent of the costs of production. Furthermore, these are items under the control of the farmer. The costs of other items, such as rent, taxes, fertilizer, seeds, etc., are determined by factors over which the farmer has little control. As has often been pointed out by students of farm management, the farmer must look primarily to the items, man labor, power, and machinery in the matter of reducing production costs. These are the factors most directly under his control, and the key to this group is the efficient use of farm machines and power generators.

Therefore, the farmer is directly affected by any reductions in cost which may be brought about by standardization.

ECONOMIC SELECTION AN EXPENSIVE PROCESS

While history is often considered to be a dry subject, the full import of this standardization movement cannot be indicated without touching upon a few of the general characteristics which have been dominant in the development of this industry. Turning back to 1850 we find vast, fertile prairies which could not be worked by the man labor available and the farm machines in use at that time. With characteristic American energy the solution was found by developing machines which would reduce man labor. Fortunately or unfortunately Divine Providence has ordained that the human race must work out its salvation by what seems to us as a long and tedious process. We must try and fail and try again. Someone has said that mankind only falls into the proper channels after trying and exhausting every possible variety of error. The development of farm machinery has been no exception to this. Field experiments have been tried on a vast scale. An ever-increasing market has been enjoyed. Competition has been keen. One after another of hand operations have yielded to the magic touch of the American inventor until today there is scarcely a farm operation but what can be performed by machinery. Under such conditions it is not surprising to find that there has been developed a large number of styles, sizes, etc. This was necessary in order to find out what was best. No limit should be placed upon future developments, no obstruction put in the way of developments now only dreamed about, but it is fair to ask if the time has not arrived when it is desirable to examine carefully what we have with a view of differentiating the best from the better. This is one of the things which standardization should accomplish. It has been going on for many years by what may properly be called the process of economic selection, often an expensive process. Standardization should make this process more orderly and less expensive. With the facilities now available it should be possible to gather facts and draw conclusions without waiting for the process of economic law to bring us face to face with the cold facts. We can never escape the workings of economic laws, but we can do our best to anticipate their results. It would appear that after seventy years of development some further formal action could be taken which would greatly benefit the industry in this particular field.

In fact, much has already been done in this direction. The working of economic selection has been accelerated by formal action. It is interesting to see what standardization has already brought about.

STANDARDIZATION NOW IN PROCESS

Information on this matter has been difficult to obtain but a diligent search has unearthed the data presented in Table II. This may not tell the complete story but it is sufficiently accurate to indicate what standardization has already accomplished as regards elimination. There is no need to discount these figures because part of the results have been brought about through "economic elimination." It only emphasizes the opportunity for formal action. To make this report complete it must be admitted that the showing for walking plows and disk harrows as reported in Table II is better than has been accomplished in practice. Although recommended for elimination we still have the left-hand plow and the cutout disk harrow. It is possible that investigations now in progress may show that there is a place for the cutout disk harrow, and therefore final judgment may well be suspended for the time, but with the left-hand plow the case is different. This implement has a place because farmers are using it, but as has been pointed out on numerous occasions its manufacture increases the price of plows and the implement will do nothing which cannot be done with the right-hand plow. It occupies a precarious economic position.

In addition to the elimination work discussed above, standardization is proceeding along other lines. The ratings of tractors, threshing machines, and silage cutters are being studied. Standard belt speeds have been adopted. Tractor hitches have been standardized. Committees are also at work upon the standardization of barn equipment, silos, spraying machines, and tractor fertilizer drills.

Looking at this standardization problem in its largest as-

TABLE I. PERCENTAGES OF THE TOTAL COSTS OF PRODUCING FARM CROPS FROM STUDIES CONDUCTED BY CORNELL UNIVERSITY AND THE UNIVERSITY OF MINNESOTA

ITEM	Hay		Oats		Potatoes		Silage Corn		Wheat	Corn Husked From Standing Stalks
	N.Y.	Minn.	N.Y.	Minn.	N.Y.	Minn.	N.Y.	Minn.	Minn.	Minn.
Man Labor	14.0	22.2	16.0	20.77	26.5	24.75	20.0	25.55	22.90	27.90
Horse Labor	12.5	11.67	22.5	25.15	21.5	18.20	27.5	30.85	25.73	31.40
Machinery	4.5	12.73	7.0	6.85	6.5	5.36	14.5	13.10	7.07	8.78
All other items	69.0	53.43	54.5	47.23	45.5	51.69	38.0	30.50	44.30	31.92

pects the following facts stand out:

The farm-operating-equipment industry is definitely committed to this project as is indicated by past accomplishments and present activities.

Standardization is a matter of importance not only to the manufacturer, seller, and user of farm-operating equipment, but to the entire nation, and it is logical to expect cooperation not only from all groups interested but also from governmental agencies.

Many of the problems involved are of a technical nature, making it logical for engineering societies such as the American Society of Agricultural Engineers and the Society of Automotive Engineers to cooperate.

The present economic conditions are such as to make it most desirable to standardize in order to reduce production and selling costs.

The farmer is just as interested as the manufacturer in reducing production costs and any assistance which can be given in this direction will strengthen this nation's economic position.

Without in any manner detracting from what has already been accomplished, or the work now in progress, the farm-operating-equipment industry has reached a stage where a comprehensive standardization program is the next logical step. In the past conditions have been such as to develop a multitude of sizes, styles, and types. We have now had sufficient experience in many lines to enable the best to be selected from the better.

A STANDARDIZATION PROGRAM ESSENTIAL

In developing a standardization program it is essential that the work be so organized as to put no obstacle in the path of future developments or to act as a curb on the intelligent exercise of individual initiative. No one can, with certainty, foretell future developments in this industry. The best we can do is to keep the path unobstructed and encourage those qualified to venture forth. It would be a calamity if standardization should be so directed as to reduce the production of farm-operating equipment to a datum plane where the door is shut to individual initiative. Such a procedure would be foreign to American ideals and entirely at variance with the best of past experience. Individual initiative must be maintained.

While many lines of standardization work are now in progress the time has come when it may be desirable to investigate the possibilities of a more comprehensive program. Conditions were never more favorable for such action. We have had a large amount of standardization experience. We have become acquainted with the possibilities and limitations in this field. On account of the diversity and completeness of the developments during the past seventy years farm-operating equipment is ripe for such work. These facts, coupled with the necessity of reducing the costs of production both in agriculture and industry, make the field most inviting.

In this connection it certainly is not out of place to review briefly the different lines which a standardization program might follow. It is a well-recognized principle in the manufacturing industry that the greater the number of sizes, styles, and types produced the larger the overhead costs per unit. This is certainly true where production does not reach a volume of some size. This point was well brought out in a paper which G. W. Crampton read before the plow and tillage implement department of your association, and which was published in the May, 1921, number of AGRICULTURAL ENGINEERING, the Journal of the American Society of Agricultural Engineers. The figures presented in Table II show that much has already been done in the matter of elimination. We are proud to be able to pay tribute to past accomplishments, but what concerns us today is to know whether all these eliminations are proper and if it is not possible to make further reductions.

The first step in a standardization program might well be a thorough survey of the field for the purpose of determining what machines, styles, sizes, and types are essential in agricultural practice. I am not unmindful of the obstacles that will be met in work of this character. Someone is certain to point out the hardships which may be brought on certain manufacturers who have spent years establishing certain lines. Looking at the problem from its broadest aspects such manufacturers might well welcome standardization work. If the products of any manufacturer are at an economic disadvantage in the trade due to the high cost of manufacture, a decreasing demand or other factors, that manufacturer is going to meet a constantly increasing sales resistance. He is handicapped. How much better that he know the facts if they can be found and begin to shape his policies accordingly. For example, take the left-hand plow; it was abandoned, at least on paper, and then reinstated. The territory where it is used is decidedly limited. The right-hand plow is recognized as standard. The manufacturer who clings to this type exclusively is certainly limiting his possibilities and carrying both types means increased overhead. It is not justified from an economic standpoint no matter if there are farmers who have never used any other type and do not expect to.

In this connection it must be remembered that a standard adopted today will not necessarily upset established routine tomorrow, rather it is a goal towards which to work making the adjustment gradually with a minimum of hardship.

Take as another example a machine which has only limited potential possibilities from a sales standpoint. Its production is divided among a number of manufacturers in such a manner that its cost is relatively high and the profits small. Once this situation is presented in a comprehensive manner it is reasonable to suppose that some manufacturers will direct their efforts into other channels leaving larger production to those manufacturers remaining in the particular field thereby reducing costs and increasing the opportunity to make a reasonable profit.

In such a program reliable statistics are of vital importance and this industry is to be congratulated that the United States Department of Agriculture has undertaken the work of collecting statistics on the manufacture and sale of farm-

TABLE II. ELIMINATION OF STYLES, SIZES, AND TYPES IN THE FARM-OPERATING-EQUIPMENT INDUSTRY

ITEM	Eliminated	Retained
Drills	32	18
Fertilizer drills	3	11
Seeders	4	3
Land rollers and pulverizers	32	12
Cream Separators	10 sizes and types	5 sizes[1]
Mowers	2	6
Hay balers	5	4
Binders (grain)	1	4
Binders (rice)	1	1
Disk harrows	53	44
Stalk cutters	10	6
Peg tooth harrows	16	31
Corn planters and drills	759	29
Riding plows	32	16
Tractor plows	6	13
Listing plows	3	4
Walking plows	179	34
Cultivators	165	10[2]
Wagons	4336	224

[1]Individual manufacturer limited to four sizes
[2]With liberal provisions as to types of rigs

operating equipment. Such information is of the highest importance in developing standardization work.

Once the base line of essential machines is established, other lines of standardization work will naturally follow.

The first of these will logically be an attempt to standardize the raw materials used in the manufacture of farm-operating equipment. Raw materials in this instance are defined not only as iron, steel, and wood, but as everything which the manufacturer buys. The best information available shows that purveyors of raw materials for this industry are required to furnish a great variety of materials for requirements which do not vary greatly as regards the ultimate use. It is certain that this field offers unusual possibilities.

There is need for more uniformity in rating farm-operating equipment. Standard methods for rating tractors and belt machines could be adopted with profit by the industry. The empirical formula has the advantage of simplicity but the very serious disadvantage of not always yielding results in accordance with the facts. The logical solution in this case would appear to be to abandon empirical formulae and develop testing codes which can be used by manufacturers for rating purposes. If ratings are to have increased significance it is essential that they be as accurate as possible.

There are many other things which lend themselves to standardization, such as belt speeds, gears, bolts, nuts, etc. These are important details which may logically be developed along with the program already discussed and will be brought to light as progress is made.

The points already discussed have a direct bearing on the industry as a whole. In addition there is much standardization work which can be carried on by individual companies entirely independent of their fellow workers in the field. In a general way an individual company might find it advantageous to follow the general program already suggested for the industry. It is not necessary to elaborate on the possibilities in this field except to point out that any standardization program which may be adopted by the industry will be stronger if supported by active standardization work on the part of the individual members.

A discussion of this subject would not be complete without reference to ways and means for making standardization work effective. It is generally accepted as foreign to American ideals to establish standardization by legislation or other equally positive means. In fact, too positive action in this field which is so influenced by mechanical and economic changes may bring disastrous results. While progress may be slower it will be far more secure if attained by agreement among the different interests involved.

It is evident that the manufacturers of farm-operating equipment hold the key to standardization work and will continue to dominate the situation if their action is constructive and conservative, but it appears to be equally certain that other groups interested, notably organized agriculture, are expecting action.

While the farm-operating-equipment industry should, and undoubtedly will, be the leader in this standardization work, to secure the greatest effectiveness is going to require not only the active cooperation of other groups interested but also the sobering influence of what are looked upon as neutral bodies, such as governmental agencies, state colleges, and technical societies. The various groups directly interested, notably the purveyors of raw materials, manufacturers of farm-operating equipment, dealers, and farmers can be depended upon to present their cases in a convincing manner. It would be unusual to find complete agreement between these groups and this is one of the points where the work and influence of neutral bodies charged more or less directly with the responsibility of the public interests will be most beneficial.

As great as are the difficulties in the path of formulating a standardization program which will be in accord with economic and mechanical developments it is no less important to give the most careful consideration to ways and means of making this work effective. In this field cooperative endeavor is especially important.

An Iceless Refrigerator*

CLIMATE, the boast of all Californians, has been responsible for the development of an iceless refrigerator. The principle involved in the operation of this refrigerator is similar to that used for years on many farms where a wet burlap bag is wrapped around the water jug used by men in the fields during the summer months. The constant evaporation of the moisture from this bag serves to keep the contents of the jug cool, even though placed in the boiling sun. The refrigerator is of concrete and is circular in shape and cast in sections. The barrel or body of the refrigerator is cast in four pieces which fit into a groove running around a circular piece which serves as a base. The edges of these four pieces are interlocking and when placed together form a barrel-shaped chamber in which food is placed. Each piece or section which makes up the wall is reinforced with galvanized steel wire. A concrete tank grooved to fit snugly over the wall of the food chamber forms the top. This top is closed from dirt and dust, the only opening in it being a small hole near the top through which the tank is filled with water and four valves at the bottom of its outer rim which regulate the flow of water over the walls below. The walls are covered on the outside with coarse pebbles to catch the water as it seeps down from the valves and evenly distribute it over the surface. This pebble covering also increases the surface area from which evaporation takes place. A concrete door with especially made hinges and latch gives access to the interior of the chamber.

Openings at the top and bottom of the walls provide a constant change of air in the food chamber. The shelves which hold the food revolve together around a central rod, giving easy access to contents. This rod rests on a round bearing set in the bottom of the chamber and fits into a socket in the botom of the tank above. The shelves are attached to it by means of set screws and can be raised or lowered to secure the desired distance between them. These shelves are of concrete only one-half inch in thickness, but will each carry a load of approximately 75 pounds. Both the interior of the chamber and the shelves are finished in white which adds greatly to their attractiveness and cleanly appearance.

The bottom of the refrigerator extends below the side walls and contains a groove which is kept full of water to keep out ants and other insect pests.

*From "The Concrete Builder," published by the Portland Cement Association.

Device to Test Roadbeds

FACTS about what happens under a roadway as traffic passes over it are being obtained by the use of an ingenious device perfected by the Bureau of Public Roads of the U. S. Department of Agriculture. Primarily the device measures, at desired distances, how the burden of traffic is distributed through the roadbed to the soil on which it rests. A thick roadbed lightens the load on every square foot of underlying earth or rock; a thin one places thereon more weight. How far distant from the surface point of contact—where load meets road—the weight is distributed and the possible formula for its distribution are being determined by experiment. When the facts are fully known and the traffic burden on the near-by and underlying soil is accurately measured, road makers will have a valuable guide as to the thickness of the roads they should construct on varying kinds of subsurface.

Agricultural Engineering Development

A Review of the Activities and Recent Progress in the Field of Agricultural Engineering Investigation, Experimentation and Research

Edited by R. W. Trullinger
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THE INFLUENCE OF WATER CONTENT AND VOID SPACE ON THE WORKABILITY OF SOIL, H. Zander, [Internationale Mitteilungen fur Bodenkunde, (Fachliteratur G.m.b., H., Berlin), 10(1920), No. 3-4, pp. 89-117, fig. 9.] Experiments with sand, loam, peat, and three different garden soils to determine the influence of water content and physical condition of soil on the resistance to cultivation are reported. The apparatus used is described and the data obtained is analyzed mathematically.

It was found that when the soils studied contained only hygroscopic moisture they were the most easily worked. This condition was apparently independent of other physical characteristics.

THE THEORY AND PRACTICE OF SANITATION IN COUNTRY PLACES, INCLUDING THE BACTERIOLYTIC TANK SYSTEM, W. R. Smith. (Adelaide, South Australia, R. E. E. Rogers, 1920, pp. 36, pls. 12.) This is the fifth edition of this publication containing the summarized results of a large amount of experience on the use of residential methods of sewage disposal. Special attention is devoted to the so-called bacteriolytic tank system, which consists primarily of a combination of settling and septic tank and ventilation system. The results of experience are said to indicate that the bacteriolytic tank should be lined with concrete and should have a capacity as nearly as possible to 24 hours sewage. It is considered unnecessary to filter or otherwise separate the constituents of sewage before it passes into the tank. The compartments may be open or closed, but if closed they should be ventilated so as to allow a constant supply of air to the second compartment.

It is further stated that filtration materials have proved unnecessary and are sometimes a source of trouble. The resulting liquid may be passed on to the soil or allowed to soak into the subsoil by means of catch wells or drains. It is stated that there is evidence to show that these tanks favor the destruction rather than the growth of germs of typhoid fever and other diseases. The pamphlet evidently is written from the Australian viewpoint.

POWDER POST DAMAGE TO TIMBER AND WOOD PRODUCTS, A. D. Hopkins and T. E. Snyder. (*Engineering News-Record*, New York, 87, 1921, No. 7, pp. 269-271, fig. 3.) In a contribution from the U. S. Department of Agriculture the nature of extensive injury by powder-post beetles to seasoned hardwood material of all kinds, finished and unfinished, is explained and methods of control and prevention are outlined.

The injury is caused by grubs which are the larvae of small beetles. These grubs, yellowish white in color and from 1/8 to 1/4 inches long, burrow through wood in all directions and convert it into powder, finally boring to the surface for the escape of the beetles. Seasoned heartwood and sapwood of both hardwood and softwood trees are attacked by different kinds of these beetles, but it is stated that by far the larger proportion of this kind of trouble is caused to the seasoned sapwood of hardwood by species of the genus Lyctus.

In the reclamation of infested wood all infested material, including sap edges of lumber and all refuse of sapwood, should be sorted out and disposed of. Material showing the slightest evidence of powder-post damage should be destroyed. This work should be done between October and March in storehouses and before April in the open air. For the more valuable stock the wood should be treated for the destruction of the insects between October and March. Pure kerosene oil may be applied with a brush or rag or the wood may be immersed in kerosene. Hot mixtures of creosote and kerosene oil and of creosote and naphtha have also been used successfully when applied by immersion or brushing. Thorough steaming of the infested wood in the dry kiln is said to be effective, the seasoned wood being heated to temperatures up to 200 degrees Fahrenheit for a short period after the usual kiln-drying operation. The damaged woodwork of buildings should also be treated with kerosene. As preventive measures, it is stated that stock which has been seasoned longer than eight months and is to be held in storage may be rendered immune by applying two coats of hot boiled linseed oil, or by immersing it in hot oil. This treatment should be given between October and March.

EXPLORATORY DRILLING FOR WATER AND USE OF GROUND WATER FOR IRRIGATION IN STEPTOE VALLEY, NEVADA, W. O. Clark and C. W. Riddell. (U. S. Geol. Survey, Water Supply Paper 467, 1920, Washington, D. C., pp. 70, pls. 6, fig. 6.) The results of studies of the surface and ground water resources of Steptoe Valley, an area of 900 square miles in east-central Nevada are reported.

These studies were made in connection with the agricultural development of the area and are considered to have a close bearing on the future of irrigation of the valley. Steptoe Valley forms a plain, the relief of which is small in comparison with that of the bordering mountains. The borders of the valley are several hundred feet and in places possibly as much as a thousand feet higher than the axis. The slope ranges from nearly level at the axis to a fairly steep grade where the borders of the Valley blend with the talus slopes of the mountains.

The soils of the valley are divided on the basis of texture into gravelly, sandy, and clayey soils, and on the basis of chemical composition into alkali and nonalkali soils. The presence of large amounts of alkali salts is due to the concentration of these salts by evaporation of surface on ground waters. Analyses of samples of soil from fourteen different points in the valley show that the total content of soluble salts varies from 0.11 to 1.15 per cent. The gravelly soils are found chiefly on the lower slopes of the mountains and on the upper parts of the alluvial fans. Most of the land that will be reclaimed in the valley is probably in the areas of sandy loam. The soils of the lower parts of the valley along its axis are composed largely of clay and fine silt.

It was found that beds of water bearing gravel underlie at least a part of Steptoe Valley. The strongest water-bearing beds discovered in the test wells drilled by the U. S. Geological Survey are within 125 feet of the surface and can therefore be tapped by relatively inexpensive wells. In the vicinity of two of the wells it is shown that properly constructed 10-inch wells will yield several hundred gallons a minute with a drawdown of 20 feet. The valley is said to contain about 185,000 acres of land that has a depth to the water table of less than 50 feet. Of this area about 80,000 acres have soil that is suitable for agriculture. The valley contains about 135,000 acres of land that has a depth to the water table of less than 20 feet, of which about 40,000 acres have soil that is suitable for agriculture. Most of the area in which the water table lies at a depth of less than 10 feet has soil that contains too much alkali to be satisfactory for agriculture, and most of the area in which the water table lies at a depth between 10 and 50 feet has good soil.

The ground water in the valley is derived chiefly from the stream waters that are poured into the valley from tributary mountain areas and from rain and snow. According to a series of measurements the perennial streams contribute about 20,000 acre-feet a year to the ground water supply. These streams drain only 22 per cent of the mountain area. It is estimated that the total quantity of water which is added to the ground water supply in the valley during an average year is probably not less than 50,000 acre-feet. It is not considered practicable to recover all this water by pumping from wells but the available supply is sufficient to irrigate year after year some thousands of acres. Ground water is being discharged through evaporation from the soil or through the growth of native plants over an area of about 115,000 acres in the valley.

The ground water of the valley, according to the analyses reported, is for the most part satisfactory in quality for both domestic use and irrigation.

The opinion is expressed that while pumping from wells for irrigation will be expensive in Steptoe Valley, market conditions are such as to warrant rather large expenditures in producing crops. Wells for irrigation should be cased with double stove pipe casing at least 10 inches in diameter and the casing should be abundantly perforated at all satisfactory water horizons. The centrifugal pump is considered to be the most practical type for irrigation.

STUDY OF EFFICIENCY OF UNDERDRAINS, H. M. Lynde. (North Carolina Station Record, 1920, pp. 67-69.) Experiments to determine the amount of run-off from underdrained land, the relation of run-off to rainfall, and the action of tile drains in lowering the ground water level on three farms in North Carolina are reported.

On the Cotton Valley farm in Edgecombe County the soils on the tract investigated are second terrace deposits. It was found that the texture of the soil is the controlling factor in the efficiency of tile drainage and that the spacing of the drains should be such as to suit average soil conditions as nearly as they can be determined. Before designing drainage systems in nonhomogeneous soils, frequent borings to a depth of 3 feet should be made to determine the soil textures. In general, it is stated that laterals should be arranged in parallel straight lines at equal distances apart and at the same average depth. The minimum economic spacing recommended is 60 feet and the maximum depth 3 feet. A run-off factor of 1/4 inch in 24 hours from the underdrained area is considered to be ample for use in the design of the mains and submains. The minimum grade recommended is 0.2 per cent, and if flatter than this the joints between tile should be projected against the entrance of silt.

In similar experiments on the Lewis farm in Pitt County it has been found that the Norfolk and Portsmouth sandy loam soils are of an open nature and respond almost immediately to tile drainage if an outlet is provided. A spacing of 120 feet and a depth of 3 1/2 feet may be adopted for laterals in these soils. The economic rate of run-off to be adopted for underdrainage systems on areas similar to this appears to be between 1/4 and 3/8 inches, in 24 hours. It has been found that there is no danger of the silting up of 4-inch tile laid on grades of 0.3 per cent or more in these soils.

Experiments at the Black Land station in Washington County on muck soil, to determine the action of underdrains in lowering the ground water level by means of sixty nine wells, indicated that it is apparently impossible to overdrain these muck soils and that tile operates successfully on a grade of 0.04 per cent in the clay subsoils of this section. No definite conclusions are drawn, and the experiments are still in progress.

ACCELERATED WEAR TESTS BY THE BUREAU OF PUBLIC ROADS, F. H. Jackson and C. A. Hogentogler. (U. S. Department of Agriculture, Bureau of Public Roads, Washington, D. C., 4, 1921, No. 2, pp. 3-21, fig. 13.) The results of a series of accelerated wear tests upon granite block, vitrified brick, and concrete pavement surfaces are reported. The purposes of the tests were to compare the behavior of various forms of the several types of pavement when subjected to especially heavy steel-tired traffic and to ascertain whether the resistance to wear of the constituent parts of the several pavement types, as determined by laboratory tests, may be considered as a reliable index of the wearing value of these materials when combined in a pavement.

The various materials were incorporated into a number of pavement sections laid in the form of a runway approximately 400 feet long by 2 feet wide. In all there were 48 sections, 21 of which were brick, 19 granite block, and 8 concrete. The base for the granite block and brick sections was 8 inches of 1 : 3 : 6 concrete laid upon compacted cylinder fill. The concrete sections were laid immediately upon the cinders. Four different 1-inch bedding courses were laid over the base in the granite block sections, namely, 1:4 dry cement mortar, sand, asphalt-sand, and tar-sand. The brick were similarly laid on sand and sand-cement cushions. Both granite block and brick were filled in the various sections severally with 1 : 1 cement grout, asphalt, tar, and asphalt and tar mastics.

The wear testing machine consists of 5 cast-iron wheels 48 inches in diameter by 2 inches wide and each weighing 1,000 pounds. The wheels are mounted inside a channel iron frame in such a way that they roll over the center 12 inches of the 24-inch test strips. Each wheel is mounted independently so as to move up and down freely and thus adjust itself to any inequalities or depressions. The machine is pulled back and forth at the rate of approximately 5 miles per hour.

It is concluded from these tests that "Bituminous-filled granite block pavements will resist the impact produced by heavily loaded steel-tired traffic as well as cement-grouted pavements. Bituminous mastic fillers are as satisfactory for this type of traffic as straight bituminous fillers. The effect of impact is tremendously increased by irregularities produced by poorly cut block. Irregularities of surface or other factors producing impact are more serious with grouted than with bituminous filled pavements. Slight variations in resistance to wear, such as occur among the commercial granite block from the Atlantic coast quarries, are of much less importance in judging the probable resistance of the block to the action of traffic than has commonly been supposed. Cement-sand bedding courses are more satisfactory than sand or bituminous-sand bedding courses."

In the tests of the brick sections it was found that the

progress of wear was similar in all sections. First, the excess filler was broken and pulled off the surface of the bricks, then a uniform wearing of the bricks occurred over the entire length of the section. This uniform wear was followed by excessive wearing in spots, causing a very rough and uneven surface. Complete failure of the section rapidly followed this uneven condition. In sections with elastic fillers the wear was confined to the areas which came in contact with the cast-iron wheels, causing ruts or grooves to develop as the test continued. In sections having non-elastic fillers the wear was of a crushing or shattering kind, causing the bricks to shear and break in areas adjacent to as well as in the path of the wheels.

It is concluded from these tests that "The edge protection offered by bituminous and cement-grout fillers is considerably greater for vertical fiber and wire-cut lug than for repressed brick. The adhesion of bituminous fillers to wire-cut lug and vertical fiber brick tends to protect the surface and to reduce the wear. With cement-grout fillers the surface becomes a rigid slab and failure occurs because of the breaking of this slab under load and consequent loosening and shattering of the brick. With cement-grout fillers and sand-cushion construction the brick must be so thick as to make a slab which will resist without excessive distortion the impact produced by the load moving over it. In such cases the cement-grout filler offers excellent support to the wire-cut lug and vertical fiber brick. The above results indicate that for sand and sand-cement cushions and for such loads as were had at Arlington (Experiment Station), thicknesses under 4 inches are impractical. For brick of sufficient thickness to form a beam which will not be broken under impact, cement grout offers better support to the edges than bituminous fillers. The bituminous fillers cushion the edges, but under certain kinds of traffic (steel tires) allow the edge to be crushed even while the filler remains intact.

"Tar and tar-mastic fillers form more rigid slabs in cold weather than asphalt and asphalt mastic, and consequently brick filled with the former tend more toward shattering than those filled with the latter. For the same conditions of brick and type of construction, brick with rounded edges offer less resistance to wear than those with square edges. Sand cushions are subject to more compression than sand-cement cushions, and the greater compression results in a more uneven surface. Elastic fillers reduce considerably the effects of impact occasioned by steel-tired traffic, and the destructive effect increase with increased rigidity of the fillers, the maximum destructive effect occurring with such fillers as have greatest rigidity. The shattering of the brick and the additional settlement noted on the cement grout sections warrant this conclusion. The resistance to wear of the various sections, as shown from the wear test, is the same as that indicated by the standard rattler test for the brick comprising the above sections."

In the tests of the concrete pavement sections it was intended to secure comparisons of the resistance to wear offered by concretes made from different aggregates. Eight sections were constructed, each 6 inches thick and each of 1:1½:3 concrete. During the progress of the test these sections, in addition to wear on their surfaces, developed a considerable number of transverse cracks followed by settling, thus subjecting them to impact. In general the wear progressed the same on all sections, beginning with a slight grooving action which gradually uncovered the large aggregate, after which the depth of wear as well as the uniformity of the resulting surface depended more or less upon the hardness and size of the aggregate. These tests showed that the trap rock and gneiss sections gave the greatest resistance to wear and presented very uniform surfaces. The gravel sections ranked next, showing slightly more wear but about the same uniformity. The limestone and sandstone sections compared favorably with the gravel as regards depth of wear but tended more toward the development of nonuniform surfaces. The slag sections showed the least resistance to wear and compared favorably with each other. It was found further that this test shows no relation between compressive strength and resistance to wear afforded by the several concretes. The dry concretes offered more resistance to wear than the wet ones.

Observations of the transverse crackling and settlement indicated that slag, sandstone, and limestone do not offer as much resistance to crackling as gravel, trap rock, and gneiss. The tests on the concrete sections indicated that neither the resistance to wear nor the resistance to crackling are dependent upon the compressive strength of the concrete as determined by 6-by-12-inch test cylinders, that more resistance to wear is afforded by dry concrete than by wet, and that the harder aggregates offer more resistance to wear than the soft ones.

RUN-OFF DATA ON DRAINAGE CANALS, H. M. Lynde. (North Carolina Station Report, 1920, p. 67.) The progress results of studies of run-off on Third Creek Canal, Iredell County, are summarized, indicating that a run-off factor of 1 inch in 24 hours over the watershed should be adopted in the design of drainage ditches in the Piedmont region of North Carolina. It has been found that the average annual run-off on Third Creek is approximately 43 per cent of the average annual rainfall. The results are also taken to indicate that the daily rainfall recorded at one station on a watershed does not represent true daily rainfall conditions. To obtain an approximate true rainfall it is necessary to average the records of several stations scattered over the watershed. For small watersheds with rainfall conditions as they are on Third Creek, one rainfall station for each 10 square miles is apparently not too frequent.

STUDIES OF IRRIGATED SOILS AND IRRIGATION WATERS, A. E. Vinson, C. N. Catlin, and S. W. Griffin. (Arizona Station Report, Tucson, 1920, pp. 436-439.) Studies of the tolerance of wheat in black alkaline soil indicated the tolerance to be somewhat over 0.2 per cent of sodium carbonate. It is noted that healthier looking plants were obtained in plots containing from 0.1 to 0.15 per cent of sodium carbonate than in those containing small amounts of alkali. The grain yields, however, were highest in the soils containing 0.05 per cent of sodium carbonate. The heaviest grain yields of all were obtained in soils containing 0.2 per cent of sodium carbonate, with sufficient gypsum added to neutralize exactly the sodium carbonate. Larger amounts of gypsum did not increase the yield, but one half and one-fourth of the amount required to neutralize the sodium carbonate gave some increase over the untreated check.

The monthly analysis of water from the Tempe drainage ditch is also reported.

Rules for the blending of pump water with canal water under the Salt River Valley project are included. These state that the blended water delivered to irrigators may contain not more than 50 parts per 100,000 of chlorid estimated as sodium chlorid, or not more than 100 parts per 100,000 of total dissolved salts. Black alkaline waters may not be blended in proportions that will give the blended water a permanent black alkaline content. Pump water that shows by analysis at the time a lower content of chlorids and total dissolved salts than the unblended water of the canal into which it is pumped may be used in any quantity.

Data are also given on the character of the ground waters immediately east of the Agua Fria River.

GRADING ROAD WITH TRACTORS AND WHEEL SCRAPERS, W. D. Hill, Jr. (*Public Works,* New York, 50, 1921, No. 20, pp. 406-408, fig. 2.) Data from the use of two outfits of a tractor and two trailers each for hauls exceeding 150 feet showing force employed, dirt removed, and dynamometer results are reported. A five-ton caterpillar tractor gave the following results in hauling:

DIRT MOVED BY 5-TON CATERPILLAR TRACTOR IN A DAY OF TEN HOURS

Distance of haul—feet	300	600	900	1320	1800	2640
With two 4-wheel scrapers—cubic yards	262	214	160	122	96	68
With three 4-wheel scrapers—cubic yards	360	270	210	150	120	90

The dynamometer tests showed that the pounds pull on the drawbar of the tractor when loading the first scraper was 4960 at a speed of one-half mile per hour, when loading the second scraper, 4520 pounds, and when loading the third scraper, 4800 pounds. The average drawbar pull when hauling three loaded scrapers at three miles per hour was 2140 pounds, when dumping at three miles per hour, 2540 pounds, when turning empty, 1160 pounds, and when returning empty, 928 pounds. The return empty was made at the rate of 5.71 miles per hour.

NEW METHOD OF DETERMINING EFFICIENCY OF CENTRIFUGAL PUMPS, A. F. Sherzer. (*Engineering News-Record,* New York, 86, 1921, No. 26, pp. 1114, 1115, fig. 3.) In a contribution from the University of Michigan, graphic data are reported from a large number of experiments with centrifugal pumps showing the relation between capacity and efficiency and between specific speed and efficiency for horizontal centrifugal pumps and the efficiencies for centrifugal pumps in terms of discharge in gallons per minute and specific speeds. The data show that, generally speaking, the maximum efficiency of a given pump will increase as the speed increases up to a certain point when a further increase in speed will cause a decrease in efficiency. Specific speed is defined as the speed in revolutions per minute at which the pump will revolve when discharging one gallon per minute against a head of one foot, and is indicated by the expression Ns.

$$Ns = \frac{N\sqrt{GPM}}{h^{3/4}},$$

in which Ns = specific speed, N = actual speed, H = head for maximum efficiency, and GPM = discharge. The data show that the efficiency of various centrifugal pumps increases quite rapidly with the specific speed until it reaches a maximum when the specific speed is about 3,000 revolutions per minute, after which the efficiency decreases slowly.

THRESHER EXPLOSIONS, H. E. Roethe. (*American Thresherman and Farm Power,* Madison, Wis., 24, 1921, No. 3, pp. 12, 47, fig. 2.) In a contribution from the U. S. Department of Agriculture, the general results of studies on the cause and remedies for thresher explosions, particularly in the State of Washington, are presented and discussed, most of which have been noted from other sources.

In connection with this work special studies were conducted in the field on the accumulation and redistribution of static electricity in threshing machines. The electrical equipment consisted of a voltmeter, a spheregap, and a galvanometer. The voltmeter and spheregap were used to measure voltage and the galvanometer to determine differences in potential. A maximum of 60,000 volts was found on main drive belts. A few hundred volts were recorded in several cases on cylinder shafts, and strong shocks were received on numerous occasions from grain pans and from metallic discharge pipes attached to special dust-collecting fans.

There was a continual marked difference in potential between the earth and the different parts of the grain threshers. Several steel machines showed, as individual units, a greater potential than the earth, every part being positively electrified. In many machines a marked difference in potential was found between the cylinder shaft and concaves, the concaves and the main flame, and between the grain pan and the main frame. This was taken to indicate that under favorable conditions the cylinder, concaves, and grain pan would become electrified to a greater extent than other parts of the machine, resulting in the occurrence of a spark during the restoration of the normal static balance.

A state of electrification existed not only upon metallic pipes through which air laden with smut or grain dust passed, but also upon metallic surfaces in contact with passing straw or grain.

THE MANAGEMENT OF SANDY SOILS UNDER IRRIGATION, H. K. Dean. (Oregon Station Bulletin, Corvallis, 177, 1921, pp. 26 fig. 13.) The results of experiments conducted at the Umatilla Branch Experiment Station, on the management of sandy soils under irrigation, which have embraced chiefly crop testing, soil moisture and irrigation methods, and fertility improvement, are summarized.

It is stated that the water distribution system should be so constructed as to provide for the use of large heads of water. The use of gates for turning the water onto the land is said to be much more satisfactory than cutting the ditch banks. The border method of irrigation has been found to be the most suitable for light soils. The use of straw has been found to prevent soil movement until the cover crop has become established. Rye has been found to be the most satisfactory nurse crop. The most economical interval of irrigation for alfalfa on medium sandy soil is said to be once in two weeks.

FLUORESCEIN AN AID TO TRACING WATERS UNDERGROUND, H. Stabler. (U. S. Reclamation Records, 12, 1921, No. 3, pp. 122, 123.) Experiments on the use of fluorescein, a coal-tar product, for the tracing of underground waters are reported.

In the first experiment a kilogram of fluorescein was placed in a stream flowing at the rate of 1.2 second-foot into a sink hole in limestone. It was next seen 24 hours later at the outlet of an underground stream flowing 2.5 second-feet and at a point 12,000 feet distant. This stream was turbid and the time required for the flow was so great that seepage through large pools was indicated.

In a second experiment fluorescein was placed in a stream flowing only 0.1 second-foot. The effluent again showed green at an outlet 4,000 feet from the inlet.

In a third experiment 2 ounces of fluorescein were placed in the sandy bed of a stream flowing 0.1 second-feet. The color appeared 1½ hours later in a spring 450 feet distant which was supposed to be free from surface contamination.

In a fourth experiment 1.5 pounds of fluorescein were placed in a sink hole in limestone. This resulted in coloring a 2-second-foot spring at a distance of 2,500 feet 25 hours later.

It is stated that, generally speaking, the dose of fluorescein should be computed to give about 1 part in 10,000,000 in the effluent to be visible to the naked eye. In tracing an underground water connection the proper method is to dissolve the calculated dose of fluorescein in a small quantity of water and place it in a single charge at the point where the water disappears underground. Then watch all possible springs or wells for results, collecting samples and examining them in a long tube of colorless glass at frequent intervals. Seepage from a canal can be traced by placing fluorescein in pits or borings alongside or in the bed of the canal.

A. S. A. E. and Related Activities

New A. S. A. E. Headquarters

ON ACCOUNT of the change in secretaryship noted on this page, the headquarters of the American Society of Agricultural Engineers will hereafter be located at St. Joseph, Michigan.

Secretary Hanson Resigns

IT IS with much regret that the announcement is made of the resignation of Frank P. Hanson as secretary of the American Society of Agricultural Engineers, which took place November 1. Mr. Hanson took up the work of assistant secretary under J. B. Davidson upon his graduation in the agricultural-engineering course at the Iowa State College in 1920, becoming secretary of the Society on January 1, 1921. During Mr. Hanson's administration as secretary the Society has made substantial growth and its activities considerably extended. His new connection is with the cement products bureau of the Portland Cement Association.

Mr. Hanson will continue as treasurer of the Society, and in his place as secretary the Council has appointed Raymond Olney, with the headquarters of the Society to be located at St. Joseph, Michigan.

Tentative Program for Annual Meeting

THE following is the tentative program for the fifteenth annual meeting of the American Society of Agricultural Engineers to be held at the Auditorium Hotel, Chicago, December 27, 28, and 29, 1921:

TUESDAY, DECEMBER 27—FORENOON

Registration.

Meeting called to order by chairman of the local arrangements committee.

President's Annual Address, Dr. E. A. White.

RECLAMATION SESSION

"New Engineering Developments in Land Clearing Methods," John Swenehart, land clearing specialist, University of Wisconsin.

"Financing of Drainage Districts," S. H. McCrory, chief of the division of agricultural engineering, U. S. Department of Agriculture.

AFTERNOON SESSION

"The Advantage of a Planned Rural Development," Dr. Elwood Mead, professor of rural institutions, University of California, and special lecturer for Harvard University.

"Flood Control in Agriculture," Arthur E. Morgan, president Antioch College, formerly chief engineer Miami Conservancy District, Dayton, Ohio.

Report of Drainage Committee. D. P. Weeks, Jr., chairman, Dakota Engineering Company, Mitchell, South Dakota.

Report of Irrigation Committee. H. E. Murdock, chairman, Montana Agricultural College, Bozeman, Montana.

Moving pictures of land-clearing operations in Wisconsin.

COLLEGE SECTION SESSION—EVENING

This session will be devoted exclusively to discussions of educational and other problems of special interest to members in the agricultural-engineering departments of the state agricultural colleges and the division of agricultural engineering of the U. S. Department of Agriculture.

WEDNESDAY, DECEMBER 28—FORENOON
FARM STRUCTURES SESSION

"Sunshine Efficiency of Hog Houses," F. C. Harris, agricultural and industrial engineer, Louden Machinery Company, Fairfield, Iowa.

"Some Recent Developments in Farm Buildings," Fred C. Fenton, associate professor of agricultural engineering, Iowa State College, Ames, Iowa. Discussion led by Arthur W. Clyde, extension associate professor in agricultural engineering, Iowa State College.

"Stuccoing Farm Buildings," J. E. Freeman, manager structural bureau, Portland Cement Association, Chicago, Illinois.

"Relative Heat Conductivity of Materials Used in Farm Building Construction," W. A. Foster, chairman, Committee on Farm Building Design.

"Barn Lot Drainage and Barn Sanitation," Ralph L. Patty, extension specialist in rural engineering, South Dakota State College, Brookings, South Dakota.

A special meeting of the Reclamation Section will be held during the forenoon of December 28 for organization and the election of officers and to hear reports of what other national and state organizations are doing in reclamation work, and for round table discussions of technical drainage, irrigation, and land-clearing problems.

AFTERNOON SESSION

"Making Good Barns Better," W. B. Clarkson, chairman, Committee on Ventilation.

"Force Draft System of Ventilation," M. A. R. Kelley, barn architect, U. S. Department of Agriculture, Washington, D. C.

"Design of Out-take Flues," J. L. Strahan, department of rural engineering, Massachusetts Agricultural College, Amherst, Massachusetts.

"A New System of Ventilation," L. J. Smith, professor of agricultural engineering, State College of Washington, Pullman, Washington.

"Code for Country Plumbing," H. H. Musselman, professor of farm mechanics, Michigan Agricultural College, East Lansing, Michigan.

"Keeping the Water Supply Pure," E. W. Lehmann, chairman, Committee on Sanitation.

"Relation of Construction to Farm Building Sanitation," C. S. Whitnah, research and extension department, King Ventilating Company, Owatonna, Minnesota.

EVENING SESSION

Annual banquet

THURSDAY, DECEMBER 29—FORENOON
FARM POWER AND EQUIPMENT SESSION

"Efficient Use of Animal Power," Wayne Dinsmore, secretary, Horse Association of America, Chicago, Illinois.

"Reducing Dockage Losses at the Separator," Robert H. Black, in charge of grain cleaning investigation, U. S. Department of Agriculture.

Report of Subcommittee on Disk Harrow Investigation, E. V. Collins, chairman, Iowa State College.

Report of Subcommittee on Left-Hand Plow Investigation, G. W. McCuen, chairman, Ohio State University, Columbus, Ohio.

AFTERNOON SESSION

"The Standard Drawbar Hitch," Mr. Lindgren, experiment department International Harvester Company, Chicago, Illinois.

"Tractor Lugs," R. U. Blasingame, Pennsylvania State College, State College, Pennsylvania.

Report of Standards Committee. Raymond Olney, chairman, The Power Farming Press, St. Joseph, Michigan.

Report of Committee on Tractor Ratings. G. W. Iverson, chairman, Advance-Rumely Thresher Company, La Porte, Indiana.

Business.

Copies of Journal to Student Branches

OWING to the frequent changes in the addresses of student branch members of the Society and in order to avoid the confusion thereby resulting in students failing to get copies of AGRICULTURAL ENGINEERING regularly, the copies of AGRICULTURAL ENGINEERING to student branch members will hereafter be sent in bulk addressed to the person designated by each student branch to receive such copies. The names of student branch members will be written on the covers of their copies so as to insure each student branch member getting his copy.

Wanted—Correct Addresses of These A. S. A. E. Members

NOTE: Mail is being returned from the addresses given below. These members, or others who know of their whereabouts, are requested to send the Secretary their correct addresses at once. Inasmuch as delivery cannot now be made, AGRICULTURAL ENGINEERING will not be mailed until correct addresses are received.

Charles J. Allen, 32 East Oak Avenue, Morristown, New Jersey.

George J. Baker, 122 Theodore Street, Detroit, Michigan.

Charles Wesley Barrell, 171 North Fourth Street, Columbus, Ohio.

Joaquim Bertino de Moraes Carvalho, Directoria Geral da Industria Pastoril Rua Matta Machando, Rio de Janeiro, Brazil, South America.

J. D. Eggleston, 1638 Iowa Street, Dubuque, Iowa.

H. Hansen, David Bradley Manufacturing Company, Bradley, Illinois.

John Howard Rees, 211 Commerce Building, Columbus, Ohio.

S. Y. Sweeney, 111 East Campbell Avenue, Roanoke, Virginia.

Applicants for Membership

The following is a list of applicants for membership received since the publication of the October issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send pertinent information relative to the applicants for the consideration of the Council prior to their election.

Lynwood W. Gray, Fort Valley, Georgia.

John Kenneth Mac Kenzie, instructor farm mechanics, Vermillion School of Agriculture, Vermillion, Alberta, Canada.

William James Gilmore, professor of farm mechanics, Oregon Agricultural College, Corvallis, Oregon.

Ralph E. Ewing, 713 Osage Street, Manhattan, Kansas.

Let's Grow!

"Every man owes a part of his time to the upbuilding of the business or profession to which he belongs."

These words of Theodore Roosevelt may with special emphasis be applied to members of the American Society of Agricultural Engineers.

That is to say, every A.S.A.E. member owes a part of his time to the upbuilding of the agricultural-engineering profession, of which our Society is the coordinating center.

A.S.A.E. members can perform a distinct service at this time to the agricultural-engineering profession in general and our Society in particular by devoting part of their time to arousing interest in the activities of the Society and securing the applications of new members.

The value of your A.S.A.E. membership increases with the increase in the membership roll of the Society, for the reason that the more members in the Society, the more we have supporting its activities and contributing to the sum total of agricultural-engineering science and development.

The American Society of Agricultural Engineers is essentially a cooperative organization; it is an association of engineers on a give-and-take basis. Each individual member has only so much to "give," but his ability and opportunity to "take" is limited only by the number of members contributing a part of their time and knowledge to A.S.A.E. activities. Obviously, therefore, the more members, the more valuable is your membership to you.

Will you help increase the Society's membership? The Secretary has plenty of application blanks and will help solicit prospective members. The least you can do is to hand him the names and addresses of prospective members. And remember that the new headquarters of the Society is located at St. Joseph, Michigan.

Now, let's grow!